FOCUS questions

- WHY DID Western science dominate the world during the first half of the twentieth century?
- WHAT FORMER certainties about the cosmos and human nature did science undermine during the twentieth century?
- WHY DID many people turn away from science in the late twentieth century?
- HOW DID styles in the arts mirror developments in science?
- WHY HAVE many people in the West come to rely on non-Western forms of medical treatment?

dropped his patient's wrist and shoved a thermometer into his mouth, the mandarin exploded with rage. "Why," he said to the attendant who accompanied him, "did you let this foreigner put this strange, hard thing inside my mouth? Can't you see that he knows nothing of medicine?" Only subsequently did Hume learn how he had offended his patient. He had read his pulse by taking his left wrist; but Chinese tradition dictated that a doctor must also check a series of pulse points on the right arm. By proceeding straight to taking the patient's temperature, Hume had exposed himself, in his patient's eyes, as an ignoramus.

It was a disappointing episode for the young physician. He realized that the authorities had sent the mandarin to report on the foreigner's practices. He hoped to make a favorable impression since he knew that official approval would expand and enrich his practice. His failure was an episode in a long, slow, and sometimes fitful story of the assimilation of Western medicine in China—which was itself a strand in a larger fabric of history: the spread of Western science—led by Western medicine and military technology, but extending to every kind of science and to scientific habits of thought—across the world. In no area was the rise of the West to world dominance more apparent than in the worldwide appeal of Western science. Hume played his own modest part in the story with increasing success. Gradually, painstakingly, he won Chinese confidence, building up support not only by successfully treating many difficult cases, but also by using the accumulated goodwill of the school for boys and girls that the Yale mission maintained alongside the clinic. Hume's experience, in microcosm, echoed that of Western influence generally.

In the twentieth century, science came to set the agenda for the world. Whereas previously scientists had tended to respond to the demands of society, now science drove other kinds of change. The pace of scientific discovery—with the dazzling revelations scientists disclosed about the cosmos, nature, and humankind—commanded admiration and radiated prestige. In Europe and the Americas, the period was convulsively innovative. A scientific counterrevolution exploded certainties inherited from seventeenth- and eighteenth-century science. Revolutions in psychology and social anthropology made people rethink cultural values and social relationships. A new philosophical climate eroded confidence in traditional ideas about language, reality, and the links between them. Ever larger and costlier scientific establishments in universities and research institutes served their paymasters—governments and big business—or gained enough wealth and independence to set their own objectives and pursue their own programs. New theories shocked people into revising their image of the world and their place in it.

The lessons of Western science proved equivocal. New technologies raised as many problems as they solved: moral questions, as science expanded human power over life and death; practical questions, as technologies multiplied for exploiting the Earth's resources of energy. Increasingly in the twentieth century, ordinary people and nonscientific intellectuals lost confidence in science. Uncertainty corroded the hard facts with which science was formerly associated. Faith that science could solve the world's problems and reveal the secrets of the cosmos evaporated.

In part, this was the result of practical failures. Though science achieved wonders for the world, especially in medicine and communications, consumers never seemed satisfied. There was no progress without problems. Every advance unleashed side effects. Technological advances seemed to privilege machines that fought wars and destroyed or degraded environments. Science seemed best at devising engines of destruction, but could only make people happy in modest ways, and did nothing at all to make them good. Even medical improvements brought equivocal effects. The costs of treatment sometimes exceeded the benefits. Health became a purchasable commodity. Medical provision buckled, in prosperous countries, under the weight of public expectations and the intensity of public demand.

As the power of science grew, more and more people came to fear and resent it and react against it. Despite its stunning successes, science proved strangely self-undermining. It stoked disillusionment, even as it spread. It disclosed a chaotic cosmos, in which effects were hard to predict, and interventions regularly went wrong. A century dominated by Western science ended with the recovery of alternative traditions that Western influence had displaced or eclipsed.

The stories of these changes fill this chapter—starting with the global diffusion of Western science, then turning back to the West to see how science changed from within, and how art mirrored the changes. In the remaining chapters, we can look at the effects of the changes on politics, culture generally, and the environment.

WESTERN SCIENCE ASCENDANT

The early twentieth-century world seethed with discontent at Western hegemony and sparkled with visions of a brighter future that political leaders, religious enthusiasts, and secular intellectuals promised or called for. Yet the allure of Western science proved irresistible (see Map 27.1). Its global appeal was twofold. First, it worked. Western military technology won wars. Western industrial technology multiplied food and wealth. Information systems devised in the West revolutionized communications, business, leisure, education, and methods of social and political control. Western medical science saved lives. Paradoxically, the only way for the rest of the world to beat the West, or catch up with it, was to "modernize"—code for imitating the West in science and technology. Second, Western science offered the promise of infallibility: of knowledge that was certain because it matched observation, fulfilled predictions, and withstood tests. Chinese revolutionaries actually called science a faith and represented "scientism" as an alternative to Confucianism.

China

The Chinese reception of Western science began in a continuous and systematic fashion in the 1860s, at the start of the "self-strengthening" movement (see Chapter 23). In 1866, Beijing's Foreign Language Institute opened a "mathematics" department. In fact, it was a Department of Science and Technology, with the aim of emulating the West or, as its first director said, "for the use of logical reasoning, methods of manufacturing and being practical," as well as mathematics strictly understood. "If we can concentrate on being practical," the director added, "and learn all the essentials, then this is the path to strengthening China." It was a promising beginning, but, as we have already seen, Chinese self-strengthening was patchy in the nineteenth century, and the absorption of Western ideas was always slow and subject to the restraining effects of mistrust of foreigners, whom Chinese continued to see, all too often, as barbaric or demonic.

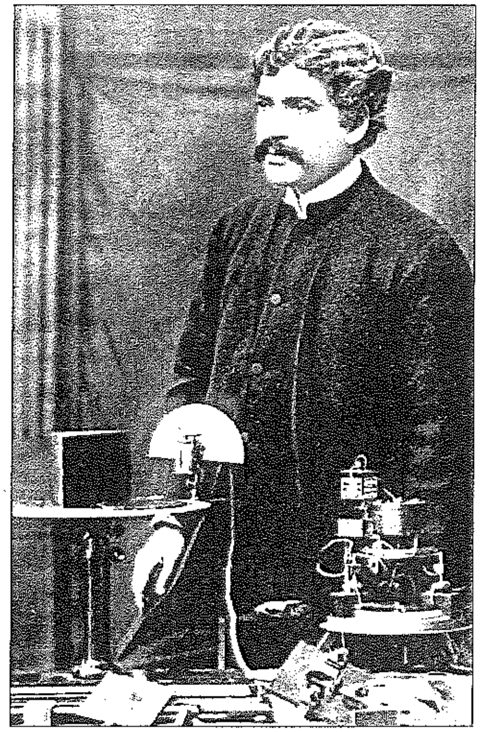
Chinese Herbal Medicine. In 1869, the emperor of China, Tongzhi, presented the United States government with 933 volumes of materials on Chinese herbal medicine and ancient Chinese agricultural techniques. This illustrated volume from the *Complete Survey of Medical Knowledge* demonstrates the proper usage of pertinent Chinese herbal medicine for illness.

Nor was the pace of change uniform in all the sciences. At first, medicine lagged behind mathematics and military and industrial technology. In 1876, for instance, a comparative study of Chinese and Western medicine by Chinese physicians upheld the superiority of ancient Chinese methods. In 1883, however, the Beijing School of Medicine launched a Western-style curriculum. Chinese students began to go abroad to study medicine. In 1900, the United States' government received an indemnity from China for the losses caused to American business interests by the chaos and bloodshed of a rebellion in China that Western forces helped to suppress. The government used the money to finance scholarships for Chinese students in America. By 1906 there were 15,000 Chinese students studying science abroad—13,000 of them in Japan, where the Western scientific curriculum was already triumphant. European and American doctors, meanwhile, acquired Chinese assistants and, in some cases, took advantage of growing Chinese interest in Western methods to move to China to practice. Dr. Hume was one of about 100 Western physicians in China in his day. In 1903, the University of Beijing acquired a medical department. Meanwhile, in essays published from 1895 onward, the scientific translator Yan Fu (yen foo) introduced Darwin's theory of evolution to China (see Chapter 25), and 20 or 30 Western scientific books were being translated into Chinese each year, with dozens more reaching China via Japan.

The revolution of 1911 that overthrew the Qing dynasty and made China a republic stimulated the pace of change, bringing to positions of power and authority intellectuals indebted to the West for many of their political ideas. They proclaimed what they called New Culture, in which science would play a prominent part, to modernize and "save" the country from Western and Japanese competition. After the revolution, syllabus reforms replaced ancient Chinese mathematics—apart from the use of the abacus—with a Western-style mathematical curriculum. Translations of Western science textbooks helped in a vital part of the process: developing a modern scientific vocabulary in Chinese. Until the term *kexue* (keh-shweh-jahng) became current from 1915, no Chinese word expressed everything the word *science* meant in English. New journals applied scientific methods and principles to social and personal problems.

Chinese who studied abroad continued to infuse China with Western intellectual influences. In 1914, Chinese students at American universities met at Cornell University in New York State to found the Science Society of China. When they returned home, it became one of the most influential organizations in the country, dedicated to popularizing Western-style science and promoting scientific education. The society succeeded. Science as Westerners understood it became part of the general curriculum, as well as the core of professional training. By 1947, for instance, China had 34,600 medical practitioners trained according to Western methods. The numbers more than doubled over the next ten years. By the end of the twentieth century, all Chinese physicians had at least some Western-style training.

In China, Western science had to rely chiefly on its inherent appeal to make headway. While the Qing had ceded a few, relatively small urban areas to foreign custody or control, in most of the country Western power was exercised only indirectly. Westerners had to buy or bribe their way into positions of influence. Yet Western science still exercised an irresistible fascination, even where it could not be forced on people. It is not surprising, therefore, that in parts of the world under the direct rule of Western empires, the uptake was even greater, for European empires acted as agents for the spread of Western science. India is the best example to concentrate on. It had a colonial government committed to promoting science and a native intelligentsia anxious to learn.



Sir Jagadis C. Bose, Indian physicist and botanist, in 1896. Bose was a professor at Calcutta and studied the polarization and reflection of electric waves. He also worked on experiments that demonstrated the sensitivity and growth rates of plants.

India

In 1899, the British viceroy of India, Lord Curzon, declared that the British had come to India to bring the benefits of their law, religion, literature, and science. The value of the first three for India might be debatable, but the benefits of "pure, irrefutable science" and, in particular, of medical science were indisputable. Science also served, incidentally, the aims of British policy, breaking through traditional barriers of caste and community, serving "rich and poor, Hindu and Mohammedan, woman and man." Curzon made the colonial government invest heavily in scientific education and the employment of Western scientists, and he induced the native princes who still ruled much of India to do the same. By 1906, India had research institutes devoted to veterinary science, agriculture, and forestry. The central government employed its own scientific research teams. By 1914, these existed for medicine, meteorology, veterinary science, botany, agriculture, forestry, and geology. In 1913, the Indian *Journal of Medical Research* was launched. These efforts were paralleled in neighboring parts of the British Empire. In Malaya, for instance, where the native elite had begun to accept Western schooling in the 1890s, the Sultan Idris Training College for Medicine opened its doors to students in 1920.

In the first couple of decades of the century, European personnel, of course, hugely predominated in the new scientific institutions. To achieve Indianization—training Indians in scientific work—the government had to overcome ingrained racial prejudice, typified in 1880 by the British Superintendent of the Geological Survey of India, who declared Indians "utterly incapable of any original work in natural science." Outstanding Indian scientists, trained in England, had to struggle for recognition, accept lower pay than their British counterparts, or take service with native princes. But their achievements gradually began to speak for themselves. In 1897, the viceroy—not without opposition from prejudiced individuals—awarded a research grant to Jagadis Chandra Bose, as "the first explorer and inventor in the electrical sciences that India has yet produced." The numbers of native scientists multiplied, thanks in part to Western-inspired educational institutions—especially the Jesuits' schools and the Indian universities the British had founded—and, in part, to the networks of education and exchange of ideas that Indian intellectuals established for themselves.

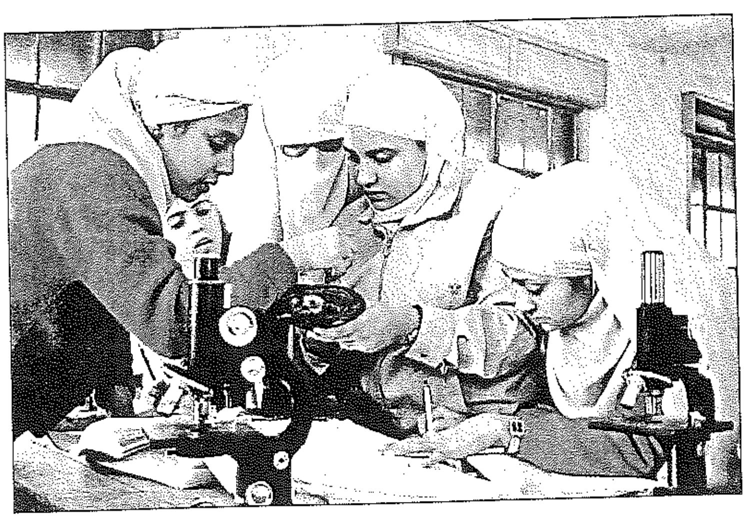
Prafulla Chandra Ray was at the heart of these networks, establishing an international reputation in chemical research and founding his own successful pharmaceutical business in Bengal. By 1920, he and his students and colleagues had published over 100 research papers, many in British and American journals. "Our age," he announced at the Indian Science Congress that year, "is preeminently an age of science. The fate of a nation will depend henceforth more upon the achievements of its students of science than upon the skill of its generals or the adroitness of its diplomatists and statesmen." In the 1920s, when the government proposed to add a chemistry department to the teams of scientists it maintained, Indian scientists opposed the idea because the teams were led by British bureaucrats, while Indian experts were better qualified for the work. In 1930, Chandrasekhara Venkata Raman, a pupil of Jagadis Chandra Bose, won the Nobel Prize in physics for work on the diffusion of light in liquids–the first non-Westerner to be so honored.

The Wider World

Though the achievements of Indian science were exceptional, the Indian model—imperial promotion of science, the multiplication of educational opportunities for natives of the country, the emergence of an indigenous scientific establishment—were reproduced in other areas of European dominion or influence in south and southeast Asia, in the Middle East, and, to some extent, in the Philippines, which was ruled by the United States.

The Indian model, however, was not followed slavishly wherever European empires ruled. In Dutch Indonesia, for instance, the reception of Western science owed little or nothing to government initiatives. Wealthy plantation owners financed an astronomical observatory at Lembang, where stargazers could escape Holland's cloudy skies in an effort to construct a reputation. The University of Leiden in the Netherlands maintained field centers in South Africa and Java. These institutions served largely as laboratories for Dutch scientists. Some scientific initiation, however, was available to Dutch colonial subjects. From 1913, Indonesians could study Western medicine without leaving their homeland. The following year, secondary schools dropped admissions policies that discriminated against native Indonesians. In 1920, local investors financed the opening of the Royal Institute for Higher Technical Education in Bandung. Its reputation as a center of scientific education quickly came to rival schools in Europe. By 1930, a third of the students at Bandung were Indonesians.

Resistance to Western science was strongest in other parts of the Islamic world, where Western dominance was absent or shaky. In the nineteenth century, the Ottoman Empire had produced many intellectuals interested in the benefits of Western science, but their work was slow to take effect. In 1900, the first Ottoman university designed on Western lines opened, but its library subscribed to no scientific research periodicals. After 1908, however, when self-styled modernizers seized control of the Ottoman government, the pace of change quickened. Learned societies in dentistry, agriculture, veterinary medicine, engineering, and geography took shape. When a European adventurer demonstrated an early airplane in Istanbul in 1909, popular revulsion forced him out of the country. But, especially after 1911, when Italian planes bombed Turkish troops in Libya during a brief war, the government took a keen interest in promoting aviation. Kemal Ataturk (keh-MAHL AH-tah-toork) (1881–1938), the leader who overthrew the Ottomans after the First World War and made Turkey a secular republic, proclaimed "science and reason" to be his legacy. Said Nursi, the enemy of Ataturk's revolution, opposed the new leader's secularism but agreed with him about the need to embrace science. He devoted his exile in the 1920s in part to demonstrating that science was compatible with Islam.



Muslim nursing students. Cairo University in Egypt, where female Muslim students wear *hijab* (headscarves). Some women students cover their faces completely. Many aspects of Western culture, including science, spread in part because they adapt easily to a variety of cultural environments. Western science has eastern roots—Islamic and Chinese influences—that many non-Westerners who study it can recognize.

On the fringes of the Ottoman Empire, and outside areas of Ottoman control, Muslim modernizers of the nineteenth century had praised science as a proper occupation for a Muslim—but without winning the argument against religious critics. One of the most influential modernizers, Jamal al-Din al-Afghani, had exposed the historic hostility of religious establishments—Christian and Muslim alike—to scientific projects. The Lebanese Shiite scholar, Husayn al-Jisr, who died in 1909, was the first great apologist for Darwin in the Islamic world. The Egyptian

Ismail Mazhir (1891–1962) continued his work in a series of translations of Darwin, beginning in the 1920s but incomplete until 1961. His great project to demonstrate that Darwin's theories were consistent with Quranic accounts of creation was still in progress at the end of the twentieth century, when the Pakistani intellectual, Ziauddin Sardar, championed it. Scientific interpretation of the Quran was, at that time, one of the most popular types of literature in the Muslim world.

Meanwhile, other forms of Western science seeped into and soaked the educational systems of much of the Muslim Middle East. Science was a foreign implant there. A survey of scientific research in the Middle East, conducted during the Second World War (1939–1945), found only a handful of Muslim scientists to consult. In 1952, a survey in Egypt counted 1,392 individual practitioners of science. At that stage, more than 70 percent of them had at least one degree from a university abroad—most from British and American institutions. By 1957, the total number of Egyptian scientists had risen to 3,600. By 1973, there were 10,655. In 1961, the great Muslim educational center of Cairo, known as al-Azhar, was reorganized along the lines of a Western university. Similar changes were under way throughout the Arab world. Over the following two decades, at least 6 million Arabs studied Western-style science at universities.

In sub-Saharan Africa, meanwhile, Western science spread more slowly and selectively. While European empires lasted, racist assumptions inhibited the colonial authorities from training native African scientific elites. Britain founded some research institutes in its East African colonies, notably Makerere University in Uganda, but their scientific staffs were recruited in England, and they educated few Africans. French research institutes had many African field centers, but these, too, were unconnected to indigenous communities. Belgian scientific work in the Congo was locally financed, but otherwise uninvolved with native Congolese. For most of the first half of the century, therefore, black Africans were the passive recipients of Western science, especially of medicine. Albert Schweizer (1875–1965), a Swiss theologian who retrained as a doctor and devoted himself to the care of the sick in

Colonial science. A British midwife instructs Burmese nurses in midwifery in the 1950s. The picture is posed to suggest Western superiority. The students—some older and presumably wiser than their teacher—are in Western-style uniforms, submissively listening to a lesson reinforced by simple diagrams.

Gabon in French West Africa for nearly 30 years, typified the spirit of the medical missionary, transforming the life expectancy of his patients not so much by his medical skill, which was never advanced, as by his efficient hospital buildings, his emphasis on hygiene, and his ability to dispense Western medicine. Thousands of idealistic young Western volunteers followed similar vocations. From the 1930s until the 1980s, as Western medicine increasingly relied on medication with new pharmaceuticals, which were invented at a dizzying pace, the power of Westerners to save African lives slashed death rates and helped bring a population explosion to Africa.

Medicine everywhere was the banner bearer of Western science, partly because that of the West probably was more effective than any other tradition, and partly because it attracted official support around the world. Missionaries valued and practiced it as an antidote to what they called superstition and magic. Western administrators saw it as a means to gain favor from indigenous elites and power over native populations who became dependent on Western medicines.

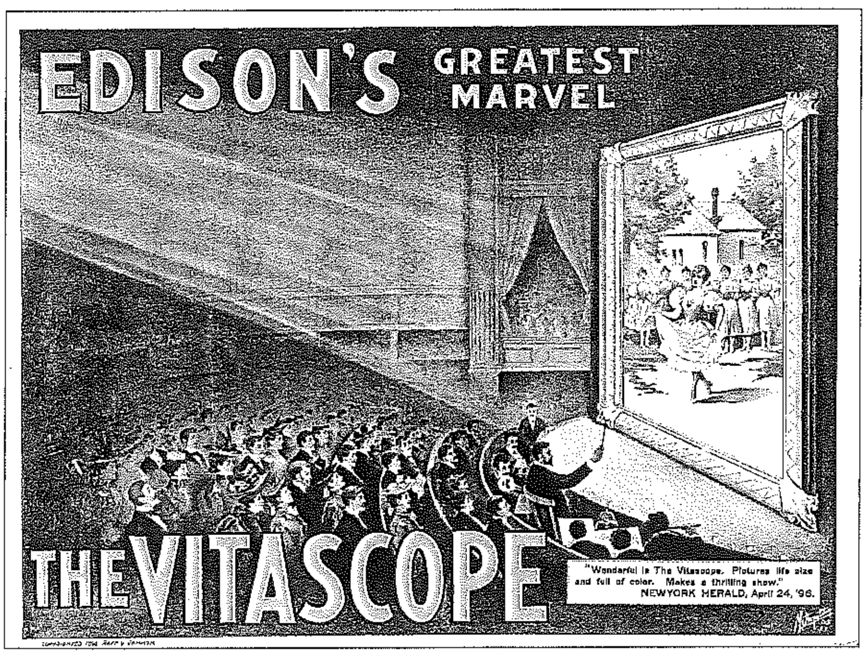
THE TRANSFORMATION OF WESTERN SCIENCE

Even while it achieved enormous influence and registered enormous effects across the world, Western science was changing from within. The very qualities that made it attractive—its benign inventions, its power to increase knowledge, its promise to disclose truths you could trust—crumbled. The inventions proved equivocal, the knowledge elusive, the certainties unattainable.

With hindsight, we can also detect the origins of the conflicts that beset science in the early twentieth century. On the one hand, they were years of impressive progress. Conventionally, historians represent the first decade or so of the new century as a spell of inertia, a golden afterglow of the romantic age that the real agent of change, the First World War, would turn blood red. But even before the war broke out in 1914, the worlds of thought and feeling were already alive with new colors. Technology hurtled into a new phase. The twentieth century would be an electric age, much as the nineteenth had been an age of steam. In 1901, Guglielmo Marconi broadcast by wireless radio across the Atlantic. In 1903, the Wright brothers took flight in North Carolina. Plastic was invented in 1907. The curiosities of late nineteenth-century inventiveness, such as the telephone, the car, and the typewriter, all became commonplace. Other essentials of technologically fulfilled twentieth-century lives—the atom smasher, the steel–concrete skyscraper frame, even the hamburger and Coca Cola™—were all in place before the First World War.

On the other hand, when the century opened, the scientific world was in a state of self-questioning, confused by rogue results. In the 1890s, X-rays and electrons were discovered or posited, while puzzling anomalies became observable in the behavior of light. In 1902, a young French mathematician, Henri Poincaré, questioned what had previously been the basic assumption of scientific method: the link between hypothesis and evidence. Any number of hypotheses, he said, could fit the results of experiments. Scientists chose among them by convention—or even according to "the idiosyncrasies of the individual." Among

The Vitascope was an early device for projecting cinematic images, displayed here showing the ballet *Giselle* in an advertisement of 1896. The gilt frame, prominent orchestra, and choice of theme all evoke the marketing context: a tasteful artform for the middle class.



examples he cited were Newton's laws (see Chapter 19) and the traditional notions of space and time. He provided reasons to doubt everything formerly regarded as demonstrable. He compared the physicist to "an embarrassed theologian, . . . chained" to contradictory propositions. His books sold in the thousands. He became an international celebrity, whose views were widely sought and reported.

Science usually affects society less by what it does or says, than by how it is misunderstood. This was particularly so for most of the twentieth century, when all academic disciplines became highly professionalized and specialized, with their own jargons and long training programs designed to exclude outsiders and amateurs. Practitioners of other kinds of learning tended to treat science as a benchmark discipline, whose objectivity they wish to emulate, but whose language and findings they could barely comprehend. Readers misinterpreted Poincaré to mean that "Scientific fact was created by the scientist," and that "Science consists only of conventions. . . . Science therefore can teach us nothing of the truth; it can only serve us as a rule of action."

Physics

Poincaré claimed that he had never intended to say or imply such things. But he set the tone for at least 100 years of struggle between science and skepticism—skepticism about our ability to know anything for certain. "The nature of our epoch is multiplicity and indeterminacy," announced the Austrian poet, Hugo von Hofmannsthal (1874–1929). "Foundations that other generations believed to be firm are really only sliding." Science seemed a laboratory transformed by the magic of a sorcerer's apprentice.

The result of this skepticism was that science, for all its achievements, could never replace ideology. It could not command ordinary people's allegiance the way that religious or political systems could. Science strode ahead, proposing solutions to theoretical problems about the nature of the universe and practical problems in every field. Its admirers and many of its practitioners came to believe in its unique virtue and even in its potential power to supplant other guides to life, such as religion, reason, instinct, and common sense. But there were always people who sneered at it, or snubbed it, or doubted its claims, or feared its consequences.

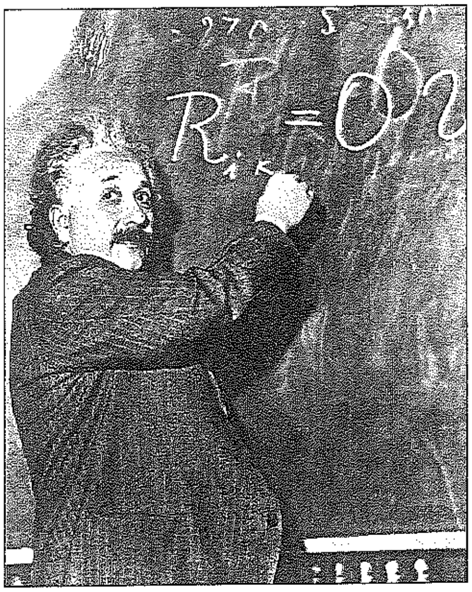
Thanks to the way Poincaré shook up perceptions of the nature of science, people became more willing to listen to radical theories from unlikely people, such as Albert Einstein (1879–1955), a minor official in the Swiss Patent Office, whose academic vocation had become frustrated because his teachers undervalued the originality of his mind. In 1905, he emerged from obscurity, like a burrower from a mine, to detonate a terrible explosion. His theory of relativity exploded traditional physics and reshaped most educated people's image of the cosmos. The impact of the explosion registered only gradually, as, up to 1915, Einstein worked out the implications of his thinking and knowledge of it spread.

According to traditional physics, and to commonplace observation and intuition, the speed of a body ought to affect the speed of the light it reflects or projects, rather as a ball gains speed from the vigor with which it is thrown. Yet experimental data, which accumulated in the 1890s, seemed to show that the speed of light never varied. Most people assumed an error in the measurements. Einstein proposed, instead, that the invariability of the speed of light was a scientific law. He resolved the contradiction by proposing that the apparent effects of motion on speed were illusions. Rather, time and space change with motion. Mass increases with velocity, whereas time slows down.

Einstein's work broke on the world with the shock of genius: the jarring sensation of seeing something obvious that no one had ever noticed before. The implications of a cosmos in which time was unfixed took a lot of getting used to.

Major Inventions—1850–1914

1852	Gyroscope
1853	Passenger elevator
1856	Celluloid
	Bessemer converter
	Bunsen burner
1858	Refrigerator
	Washing machine
1859	Internal combustion engine
1862	Rapid-fire gun
1866	Dynamite
1876	Telephone
1877	Phonograph
1879	Incandescent lamp
1885	Motorcycle
	Electric transformer
	Vacuum flask
1887	Motorcar engine
1888	Pneumatic tire
	Kodak camera
1895	Wireless radio
	X-rays
1897	Diesel engine
1902	Radio-telephone
1903	Airplane
1911	Combine harvester



Theoretical physicist Albert Einstein writes an equation on a blackboard while turning to his audience at the California Institute of Technology, ca. 1931. Einstein's distinctive looks—the ever-alert eyes, the deliberately disordered hair—became the universal image of a "typical," perhaps ideal, scientist.

In Einstein's universe, every appearance deceived. Mass and energy could be changed into each other. Twins aged at different rates. Parallel lines met. The curvature of the trajectory of light literally warped the universe. Intuitive notions vanished as if down a rabbit hole to Alice's Wonderland. Scientists hungered for an explanation that would resolve the apparent contradictions. Nonscientists were confused. Beyond doubt, however, experiment confirmed that, broadly speaking, Einstein was right. "The spirit of unrest," the *New York Times* said in 1919, "invaded science."

While Einstein proposed a restructured universe, other scientists repictured the tiniest particles, or *quanta* of which the universe is composed. Ernest Rutherford's work in Britain in 1911 proved a conjecture first discussed in the 1890s: that atoms consist of masses and electric charges, including a *nucleus* surrounded by *electrons*. The basic structure of matter, it seemed, was being laid bare. But it kept dodging and slipping out of the experimenters' grasp. For the rest of the century, ever smaller particles, ever more elusive charges continued to come to light. Between 1911 and 1913, work on atomic structures revealed that electrons appear to slide erratically between orbits around a nucleus. Findings that followed from the attempt to track the untrappable particles of subatomic matter were expressed in a new field of study called **quantum mechanics**.

The terms of this new science were paradoxical—like those employed by the Danish Nobel Prizewinner, Niels Bohr (1885–1962), who described light as consisting, simultaneously, of both waves and particles. By the mid-1920s, more contradictions piled up. When the motion of subatomic particles was plotted, their positions seemed irreconcilable with their momentum. They seemed to move at rates different from their measurable speed and to end up where it was impossible for them to be. Working in collaborative tension, Bohr and his German colleague, Werner Heisenberg (1901–1976), proposed a principle they called uncertainty or indeterminacy. Their debate provoked a revolution in thought. Interpreters made a reasonable inference—observers are part of every observation, and there is no level of inspection at which their findings are objective.

This was of enormous importance because practitioners of other disciplines at the time—historians, anthropologists, sociologists, linguists, and even students of literature—were seeking to class their own work as scientific, precisely because they wanted to escape from subjectivity. It turned out that what they had in common with scientists, strictly so-called, was the opposite of what they had hoped—they were all implicated in their own findings.

Maybe it was still possible to pick a way back to certainty by following mathematics and logic. These systems, at least, seemed infallible, and they guaranteed each other. Mathematics was reliable because it was logical and logical because it was mathematical—or so people thought, until 1931, when the Czech logician, Kurt Gödel, severed mathematics from logic and showed that both systems, ultimately, must yield contradictory results.

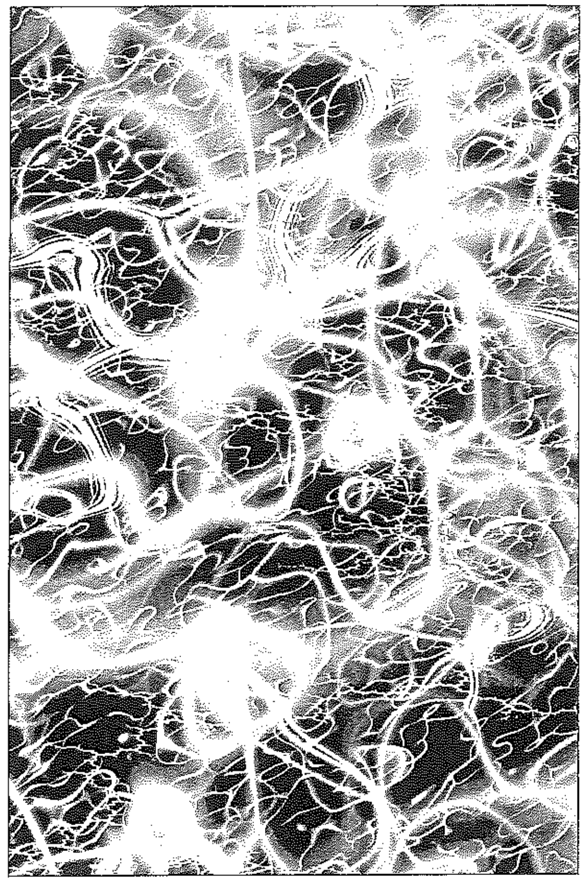
Gödel, inspired an unintended effect. He thought, like many earlier philosophers, that we can reliably grasp numbers, but he helped make others doubt it. He believed that numbers really exist, objectively, independently of thought, but he provided encouragement to skeptics who dismissed them as merely conventional. The effect of Gödel's demonstrations on the way the world thinks was comparable to that of termites in a wooden ship that the passengers had thought was watertight. If mathematics and logic leaked, science would sink. "Logics die" was the comment of the Irish poet, Brendan Behan (1923–1964).

Of course, the implications of the discoveries of Bohr, Heisenberg, and Gödel took a long time to change minds. Only gradually, through percolation within the scientific community and vulgarization in the press and popular science books, could they modify how ordinary people thought about the world. In the light of the theoretical contributions of quantum science and revolutionary logic and mathematics, however, the world was beginning to look increasingly disorderly. Meanwhile, practical discoveries and empirical observations jarred, even more uncomfortably, the equilibrium of the old picture of the cosmos.

In 1929, thanks to a powerful new telescope operated at Mount Wilson, near Los Angeles, by Edwin Hubble, the universe was found to be expanding. It seemed so strange a finding that some physicists sought to explain away the evidence for 50 years. By the 1970s, however, most cosmologists took the view that expansion started with a **big bang**, an explosion of almost infinitesimally compressed matter, which is still going on. For some interpreters, notably Pope John XXIII (r. 1958–1963), this was evidence of divine creation, or, at least, a description of how God did it. For others, it was a naturalistic explanation of change in the universe that made divine intervention an unnecessary hypothesis.

Contributions later in the century only seemed to put more space between science and certainty. In 1960, in one of the most challenging works a philosopher ever wrote about science, Thomas Kuhn argued that scientific revolutions were the result not of new discoveries about reality but of what he called paradigm shifts, changing ways of looking at the world, and new ways of expressing them. Most people drew an inference Kuhn repudiated—that the findings of science depended not on the objective facts but on the mindset of the inquirer.

In the 1980s, **chaos theory** cast doubt on one of the blessings science still promised for the world. Science specialized in inferring laws from experience and using those laws to make predictions about the future. Chaos theory made the world seem unpredictable. The idea emerged in meteorology, as a result of the dawning awareness that weather systems are so complex that, ultimately, causes and effects are untraceable. A butterfly flapping its wings, according to an image that became the most popular way to sum up the theory, can work up a storm. There is still, according to this way of thinking, some deep order in nature, some chain of cause and effect in which the whole of experience is linked—but we cannot see it whole.

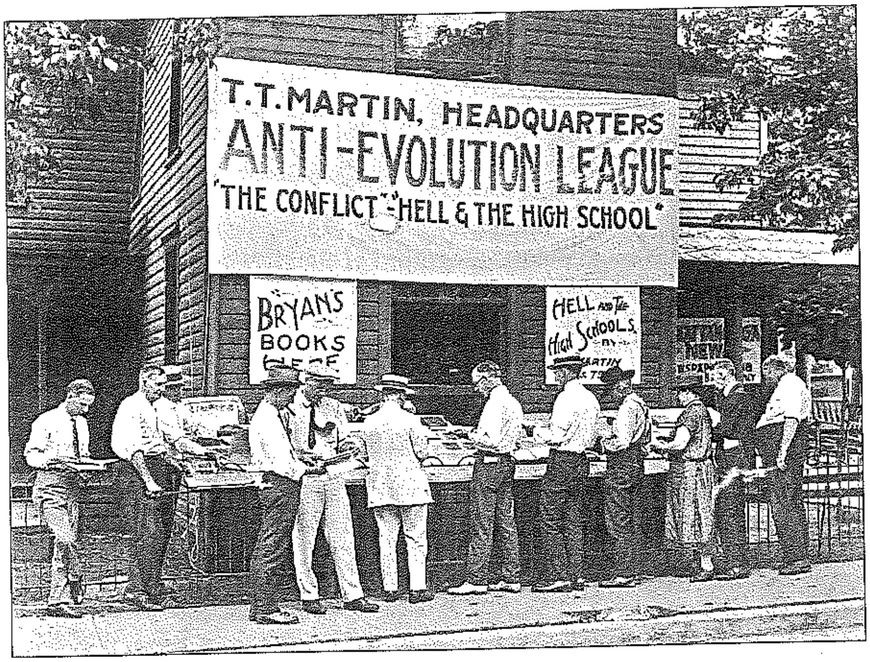


Superstrings. The superstring theory is a "Theory of Everything" (or "Grand Unification Theory") that seeks to unite gravity as a force along with the other fundamental forces (electromagnetism and nuclear forces). The theory states that fundamental particles such as quarks and electrons are not points of energy or matter, but result instead from the vibrations of "string-like" entities that are much smaller.

Throughout these shake-ups, workers in theoretical physics never abandoned the search for a comprehensive way to explain the cosmos—a "theory of everything" that would resolve the contradictions of relativity theory and quantum mechanics. The way matter behaves—at least, the way it behaves when we observe it—is riddled with paradoxes that subtle thinking has to reconcile. By the end of the century, cosmologists were proposing terms for understanding the universe that described nothing anyone had ever experienced or could easily imagine: infinite dimensions, superstrings, supersymmetry, supergravity. No experiment validated any of these models of how the universe is structured.

Human Sciences

In some respects science did deliver measurable progress. Two fields of study transformed human biology. Beginning in 1908, T. H. Morgan at Columbia University in New York initiated experiments in animal breeding that ultimately demonstrated how some characteristics are inherited by means of the transmission of genes. This led, in the second half of the century, to a new form of medicine in which doctors could manipulate people's genes to treat disease. Meanwhile, neuroscience made



Evolution on trial. People gather at an open air bookstall during the Scopes "Monkey Trial" in Dayton, Tennessee in 1925 to examine the antievolution offerings. Books by William Jennings Bryan, the former presidential candidate who led the struggle to ban evolution from the public school curriculum, are prominently advertised.

enormous progress in mapping the brain, demonstrating the distribution of mental functions, and recording how electrical impulses and releases of proteins occur, as different kinds of thinking, feeling, memorizing, and imagining take place.

Partly as a result of progress in human biology, practical medicine registered spectacular advances. Doctors could control diseases ever more effectively by imitating the body's natural hormones and adjusting their balance. That story began in 1922 with the isolation of insulin, which controls diabetes. In 1931, penicillin was discovered. It was the first *antibiotic*—a killer of microorganisms that cause disease inside the body. Preventive medicine made even bigger strides, as inoculation programs and health education became—gradually, during the century—available almost everywhere.

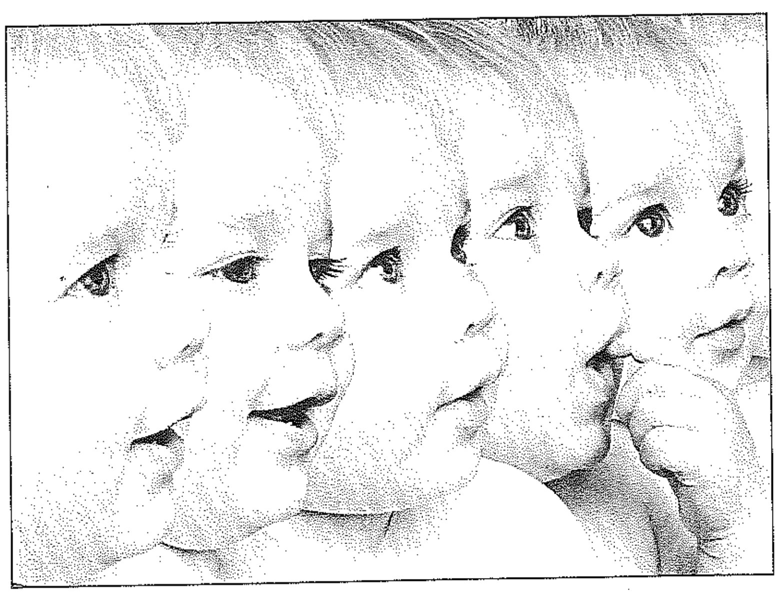
Many of the fiercest battles concerned biology, where advances challenged people to rethink human nature. In 1925, in a notorious case in Tennessee, an American court upheld the right of school boards to ban Darwin from the curriculum, on the supposed grounds that the theory of evolution was incompatible with the Bible. Belief in creation and belief in evolution are not necessarily contradictory. Evolution, which is the most convincing description we have of how and why species change, could, to a religious mind, be part of God's creation and Providence's plan. But simplistic-minded people on both sides of the debate kept picking fights with one another. Cases over whether schools could or should be compelled to teach evolution are still cropping up in courts in Europe and America, affecting Muslim as well as Christian schools. In some ways, evolution became more controversial as its proponents' claims became more strident. Some late twentieth-century Darwinians claimed to have found an evolutionary explanation for morality, for instance, and even to be able to explain cultural change in evolutionary terms. These claims got headlines but left most people unconvinced.

While disputes about evolution rumbled, the new science of genetics posed even more searching problems. In 1944, the Austrian physicist, Erwin Schrödinger, predicted that a gene would resemble a chain of basic units, connected like the elements of a code. His speculations invigorated the search for "the basic building-blocks" of life. A few years later, scientists in England, built up the picture of what DNA (deoxyribonucleic acid) was really like. Genes in individual genetic codes—it soon emerged—were responsible for some diseases, and perhaps for many kinds of behavior that changing the code could regulate. The codes of other species could be modified to obtain results that suit humans: producing bigger plant foods, for instance, or animals designed to be more beneficial, more palatable, or easier to transform into human food.

This discovery shed painfully strong new light on an old controversy—the **nature versus nurture** debate. On one side of the conflict were those who believed that character and capability were largely inherited and therefore could not be changed by "social engineering." Ranged against them were those who believed that experience—nurture—produced these qualities, and that social change can therefore improve our moral qualities and collective achievements. Genetic research seemed to confirm that we inherit more of our makeup than we have traditionally supposed. Meanwhile, sociobiology, a new synthesis devised by the ingenious Harvard entomologist, Edward O. Wilson, rapidly created a scientific constituency for the theory that evolutionary necessities determine differences between societies and that we can rank societies accordingly. Two fundamental convictions survived in most people's minds: that individuals make themselves, and that society is worth improving. Nevertheless, genes seemed to limit our freedom to equalize the differences between individuals and societies. Genetic and sociobiological claims inhibited reform and encouraged a mood we shall examine in the next two chapters: the prevailing conservatism of the late twentieth and early twenty-first centuries.

By the 1990s, genetically modified plants promised to solve the world's food-supply problems. The potentially adverse economic and ecological consequences, as we shall see in Chapter 30, evoked a chorus of protest. Modification of human genes presented more profound problems and provoked more profound unease. On the one hand, it promised a brighter future—eliminating genetically transmitted disease and enabling infertile couples to have children. On the other, it posed terrifying moral questions, best illustrated by the controversy over therapeutic cloning of human embryos, which was developed in the 1990s. This meant breeding or "farming," as people said, human embryos to extract useful cells from them. A woman could produce as many embryos as she might wish and pick the healthiest or most perfect specimens, or those she most preferred. The rest could be stored but, at some stage, would have to be discarded. In effect, this meant destroying human beings, since embryos, whatever their status in other respects, are unquestionably human. In the early twenty-first century, "designer babies" were already being produced where the process could prevent genetically transmitted diseases.

Research into less morally troubling methods of treatment would soon replace therapeutic cloning for infertile couples and to treat inherited disease. But the prospect of designer babies selected for particular features of character or appearance was even more troubling. It might lead to people capriciously cloning and discarding embryos to engineer children for themselves with fashionable looks or exploitable talents. The prospect arose that some societies would want to engineer human beings along the lines once prescribed by eugenics—improving the human species through controlled breeding. Governments could legislate supposedly undesirable personality genes out of existence. States could enforce normality at the expense, for instance, of genes supposed to dispose people to be criminal, or homosexual or just plain uncooperative. Morally dubious visionaries foresaw societies without disease or deviancy. In a world recrafted, as if by Frankenstein, humans now had the power to make their biggest intervention in evolution yet: selecting unnaturally not according to what is best adapted to the environment, but according to what best matches what humans happen to want at a particular moment. In 1995, a coalition of self-styled religious leaders in the United States signed a declaration opposing the patenting of genes on the grounds that they were the property of their real creator: God. The World Health Organization, UNESCO, and the European Parliament all condemned human cloning as unethical. Many countries banned it.



Subtle nightmare: the fear that human cloning could suppress individuality and eliminate diversity is cleverly aroused in this seemingly charming and innocent scene. But these are not real babies: On close examination the computer-generated images look disturbingly identical.

Meanwhile, the genetic revolution profoundly affected human self-perceptions, nudging people toward a materialist understanding of human nature. It became increasingly hard to find room in human nature for nonmaterial ingredients, such as mind and soul. "The soul has vanished," announced Francis Crick, a leading pioneer of genetic research. Cognitive scientists subjected the human brain to ever more searching analysis. Neurological research showed that thought is an electrochemical process in which synapses fire and proteins are released. These results made it possible, at least, to claim that everything traditionally classed as a function of mind might take place within the brain.

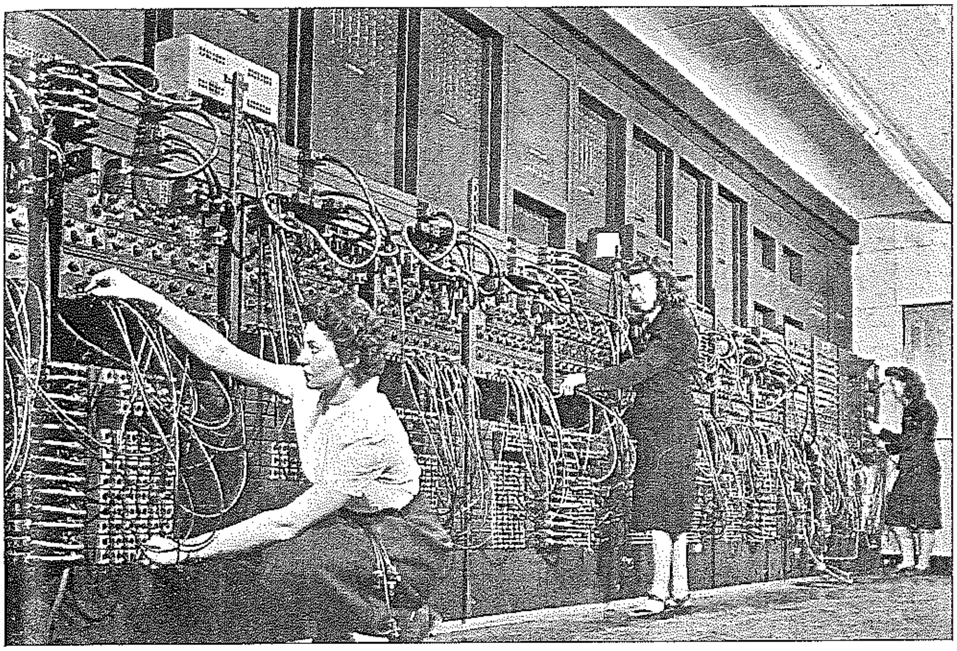
Artificial intelligence (AI) research reinforced this claim—or tried to—with a new version of an old hope or fear: that minds may not even be organic but merely mechanical. Pablo Picasso (1881–1973) painted a machine in love in 1917. Robots became the antiheroes of science fiction—the imaginary next stage of evolution, who would inherit the Earth from humankind. In the second half of the century, computers proved so dextrous, first in making calculations, then in responding to their environments, that they seemed capable of settling the debate over whether mind was different from brain. The debate was unsatisfactory because people on either side were really talking about different things. Proponents of artificial intelligence were not particularly concerned with building machines with creative, artistic imaginations, or with intuitive properties, or with the ability to feel love or hatred—qualities that opponents of AI valued as indicators of a truly human mind. Only working on ever more sophisticated robotics and seeing whether robots with highly complex circuitry developed the cognitive properties humans have could resolve these kinds of questions.

Meanwhile, two areas of scientific research previously thought to be of purely academic interest posed a further challenge to human self-perception: primatology (the study of apes, monkeys, and their ancestor-species) and paleoanthropology (the study of prehistoric humans and their ancestors). Paleoanthropologists discovered, among remains of humans' nonhuman ancestors and related primates, features formerly thought unique to our own species, *Homo sapiens*. The most challenging discoveries came from Neanderthal burials, which demonstrated that Neanderthals, who belonged to a species different from ours, had ritual lives and moral practices, including care of the elderly and reverence for the dead. Skeptics displayed apelike agility in challenging these facts—explaining them away as the result of accident or fraud. But there was too much evidence to discount altogether. It proved, in combination, that nonhuman species have existed who were morally indistinguishable from human beings. The question was important because, as we shall see in Chapter 29, it emerged at a time when the notion of **human rights** became current—a notion based in part on the assumption that being human constitutes a meaningful moral category that excludes nonhuman creatures.

Jane Goodall, *"The Challenge Lies in all of Us"*

Animal rights movements challenged that assumption. Improved knowledge of surviving species of nonhuman primates tended to support them. First, scientists working with macaque monkeys in Japan realized that these creatures, though modestly endowed with brains, have culture. They can learn and transmit what they learn across generations. The breakthrough discovery came in 1952, when a monkey called Ima was observed teaching her community how to wash the dirt off sweet potatoes. The tribe took up the technique. The monkeys continued to practice it, even when supplied with ready-washed potatoes, showing that washing had become a cultural rite, not a practical measure.

In subsequent decades, led by a brilliant field-worker, Jane Goodall, primatologists came to realize that chimpanzees have, albeit to a much smaller extent than human beings, all the features of culture that were formerly thought to be



The Electronic Numerical Integrator and Computer—one of the first electronic digital computers in the United States—was commissioned by the U.S. Army and installed, at first, at the University of Pennsylvania in Philadelphia. The choice of female programmers was presumably dictated by the public relations objectives of this photograph.

peculiarly human, including toolmaking, language, war, rules for distributing food, and political habits. Further studies of other social animals—beginning with other great apes, such as gorillas and orangutans, and, by early in the twenty-first century, including whales, dolphins, elephants, and even rats—seemed to show disturbingly similar results, suggesting that culture is uniquely human only as a matter of degree. Meanwhile, many observations and experiments cast doubt on the belief that humans have unique cognitive properties. Nonhuman apes, for example, proved to be self-aware and showed sensibilities hard to distinguish in practice from the senses of morality and transcendence formerly thought to be human peculiarities. By the end of the twentieth century, some ethicists were campaigning for animal rights or for the redefinition of the moral community to embrace great apes.

The discoveries of primatologists and comparative zoologists belonged in a broader context of scientific change: the rise of ecology, the study of the interconnectedness of all life and its interdependence with aspects of the physical environment. The development of ecology—ecologists' exposure of a vast range of new practical problems arising from human overexploitation of the environment—became a major source of influence on changes in the late twentieth-century world. Chapter 30 is devoted to discussing them.

Anthropology and Psychology

In anthropology, as in science, the opening decade of the twentieth century was decisive. Among the supposedly scientific certainties the late nineteenth-century West treasured was that some peoples and societies were evolutionarily superior to others: an image of the world sliced and stacked in order of race. This picture suited Western imperialists, who treated it as justification of their rule over other peoples (see Chapter 25). But it was upset in the first decade of this century, largely thanks to an undersung hero: Franz Boas (1858–1942). He showed that no race was superior to any other in brainpower. He made untenable the notion that societies could be ranked in terms of a developmental model of thought. People, he

Franz Boas, from *The Mind of Primitive Man* concluded, think differently in different cultures not because some have superior mental equipment but because all thought reflects the traditions to which it is heir, the society that surrounds it, and the environment in which it exists.

At the end of the first decade of the century, he summarized his findings: "The mental attitude of individuals who . . . develop the beliefs of a tribe is exactly that of the civilized philosopher."

> There may be other civilizations, based perhaps on different traditions and on a different equilibrium of emotion and reason, which are of no less value than ours, although it may be impossible for us to appreciate their values without having grown up under their influence. The general theory of valuation of human activities, as developed by anthropological research, teaches us a higher tolerance than the one we now profess.[1]

As well as a teacher, who dominated anthropology in the United States, Boas was a field-worker in his youth and a museum keeper in maturity—in touch with the people and artifacts he sought to understand. His pupils had Native American peoples to study little more than a railway ride away. The habit of fieldwork piled up enormous quantities of data to bury the crude hierarchical schemes of the nineteenth century. The new anthropology took a long time to spread beyond Boas's students. But it was already influencing British methods in the first decade of the twentieth century, and the other major centers of anthropological research in France and Germany gradually accepted it.

The result was **cultural relativism**: the doctrine that we cannot rank cultures in order of merit but must judge each on its own terms. As we shall see in Chapter 30, this proved problematic. Should cannibals be judged on their own terms? Or cultures that licensed slavery or the subjection of women? Or those that practiced infanticide or head-hunting or other abominations? Or even those that condoned relatively milder offenses against values the West cherished—offenses such as the mutilation or torture of criminals or female circumcision? Cultural relativism had to have limits, but anthropology compelled educated people everywhere to examine their prejudices, to see merit in cultures they formerly despised, and to question their own convictions of superiority.

Margaret Mead. "I lived like a visiting young village princess. I could summon informants to teach me everything I wanted to know: as a return courtesy, I danced every night." The photograph shows the celebrated anthropologist Margaret Mead (1901–1978) in Samoan dress with her collaborator Fa'amotu. Fieldwork seems to have been a liberating experience for Mead.

The noble savage (see Chapter 22) reemerged from the eighteenth-century Enlightenment. Perhaps the most influential anthropological book of all time was Margaret Mead's *Coming of Age in Samoa*, published in 1928. Mead worked with pubescent girls in a sexually permissive society. She claimed to find a world liberated from the inhibitions, hang-ups, anxieties, and neuroses that psychology was busily uncovering in Western cities and suburbs. In the long run, as she rose to the top of her profession, to academic eminence, and social influence, her work helped to feed fashionable educational ideas: uncompetitive schooling, rod-sparing discipline, cheap contraception.

Western educators could learn from Samoan adolescents in a world without barbarians and savages, where the language of comparison between societies had to be value free. What had once been called "primitive cultures" and "advanced civilizations" came to be labeled "elementary structures" and "complex structures." The longstanding justification for Western imperialism—the civilizing mission—lapsed, because no group of conquerors could any longer feel enough self-confidence to impose their own standards of civilization on their victims.

Psychology was even more subversive than anthropology, because its discoveries or claims reached beyond the relationships between societies to challenge the notions individuals had about themselves. In particular, the claim, first advanced by an Austrian psychiatrist, Sigmund Freud (1856–1939), that much human motivation is subconscious, challenged traditional notions about responsibility, identity, personality, conscience, and mentality. In an experiment Freud conducted on himself in 1896, he exposed his own *Oedipus Complex*, as he called it: a supposed, suppressed desire—that he believed to be subconsciously present in all male children—to supplant his father. In succeeding years he developed a technique he called **psychoanalysis**, designed to make patients aware of their subconscious desires. Hypnosis or, as Freud preferred, free association, could retrieve repressed feelings and ease nervous symptoms. Many patients who rose from his couch walked more freely than before.

Freud seemed able, from the evidence of a few of his patients, to illuminate the human condition. Every child—he claimed to show—experienced before puberty the same phases of sexual development. Every adult repressed similar fantasies or experiences. Women who only a few years previously would have been dismissed as hysterical malingerers became, in Freud's work, case studies from whose example almost everyone could learn. This made an important indirect contribution to the reevaluation of the role of women in society (see Chapter 29). Freud's science, however, failed to pass the most rigorous tests. When the philosopher Karl Popper asked how to distinguish someone who did not have an Oedipus complex from someone who did, the psychoanalytic fraternity had no answer. Nevertheless, for some patients, psychoanalysis worked.

Ellen Key, from *Century of the Child*

Returnees from the horrors of twentieth-century wars became patients of psychiatry. The nightmares of trench survivors in the First World War (see Chapter 28) were too hideous to share with loved ones, their experiences unimaginable to people back home. The guilt of those who missed the war echoed the shellshock of those who fought it. Introspection—formerly regarded as self-indulgence—became routine in the modern West. Repression became the modern demon and the analyst an exorcist. The "feel-good society," which bans guilt, shame, self-doubt, and self-reproach, was among the results. So was the twentieth- and twenty-first century habit of sexual candor. So was the fashion—prevalent for much of the twentieth century—to treat metabolic or chemical imbalances in the brain as if they were deep-rooted mental disorders. The good and evil that flowed from Freud's theory are nicely balanced and objectively incalculable. Psychoanalysis and other, sub-Freudian schools of therapy helped millions and tortured millions—releasing some people from repressions and condemning others to illusions or futile treatments.

Sigmund Freud on holiday in 1913 with his daughter Anna, who herself became a distinguished psychoanalyst. It was a momentous year for Freud. His most brilliant disciple, Carl Jung, broke with the master, and Freud published *Totem and Taboo*, which he later privately repudiated as "a scientific myth," full of inaccuracies. Feeling defensive about the reputation of his work he wrote *The Claims of Psychoanalysis to Scientific Interest* in the same year.

The most profound influence psychology exercised was not, however, on the treatment of mental disorder but on the way children were raised. In 1909, the Swedish feminist Ellen Key proclaimed the rediscovery of childhood. Children were different from adults. This was, in effect, a summary of the state of the idea of childhood as it had developed in the nineteenth-century West (see Chapter 24). It was, perhaps, a valid observation. But it had questionable consequences for the way children were brought up. Children who were not treated as adults in childhood "never grew up," like the tragic hero of J. M. Barrie's classic play of 1911, *Peter Pan*, who withdrew into Neverland and whose childhood sweetheart outgrew him. Generations raised on the assumption that they could not face adult realities found themselves deprived of truths about their own lives and became fodder for the new therapies of psychiatry. Generational "hang-ups" became a new curse for Western children. People outside the West, where the new image of childhood arrived patchily and late, had fewer such troubles.

In the West, better treatment for childhood disease enabled more children to lead longer lives. So children became more suitable objects in whom to invest time and emotion and, of course, study. Working on Freud's insights, educational psychologists in the West built up a picture of mental development in predictable, universal stages, as people grow up. School curricula changed in the 1950s and

1960s to match the supposed patterns of childhood development. Generations of schoolchildren were deprived of challenging tasks because child psychology said they were incapable of them. While formal education got longer and longer, most children emerged from it with no experience of traditional elements of the curriculum that were now thought unsuitably difficult, such as calculus, foreign and classical languages, sophisticated vocabulary, ancient authors, even grammar. Other developments, which belong in Chapter 29, stimulated this trend, including, notably, the economic changes that made vocational qualifications seem disproportionately important in education, and the social pressures that made for "dumbing down."

Philosophy and Linguistics

To scientific uncertainty and cultural relativism, the opening decade of the century added potentially devastating philosophical unease. In combination with Einstein's disquieting revelations about the nature of time, the theories of the French philosopher Henri Bergson (1859–1941) proved both unsettling and inspiring. He formulated a concept he called "duration"—the new sense of time we get when consciousness "abstains from establishing a separation between present states and the preceding states." This seemingly difficult idea helped to fortify educated people's faith in free will. Time is not a constraint that nature imposes on us, but a concept that we impose on nature. Bergson coined the term *élan vital* to express the freedom we retain to make a future different from the one that science predicts—a spiritual force with the power to reorder matter. Time, the way Bergson saw it, became not a sequence of atomized events, but a product of memory, which is different from perception and therefore "a power independent of matter."

Bergson's thinking infuriated scientists and inspired artists. Novels written in the **stream of consciousness** were among the results. He argued that the theory of evolution needed rethinking. Evolution was not a scientific law but an expression of the creative will of living entities, which change because they want to change. Critics accused Bergson of irrationalism on the grounds that he was attacking science and representing objective realities as purely mental concepts. Indeed, consistent with his principles, he never tried to demonstrate the validity of his ideas by logical exposition or scientific evidence. This did not diminish their attractiveness or their effectiveness in liberating people who felt limited or inhibited by all the supposedly scientific determinism of the early twentieth century. Bergson reassured those who doubted whether, for example, history really led inevitably to the revolutions Marx predicted, or to the white supremacy "scientific" racism preached, or to the destruction the laws of thermodynamics predicted. Nature was unorganized. The chaos that made scientific minds despair offered hope to Bergson's readers.

Bergson's followers hailed him as the philosopher for the twentieth century. His first great rival for that status was an American, William James (1842–1910). The start of James's tragedy was his family's prosperity—he felt guilty when he was not earning his own living. Inside the philosopher, a capitalist was always striving to get out. James wanted a distinctively American philosophy, reflecting the values of business and hustle. He joined patriotic organizations, resisted attempts to Europeanize him, and always scampered back thankfully to America from trips abroad.

Seeking reasons to make other people share his belief in God, he argued that "if the hypothesis of God works satisfactorily in the widest sense of the word, it is true." He called this doctrine **pragmatism**. The work in which he popularized it in 1907 was hailed as the philosophy of the future. But what one individual or group finds useful, another may find useless. James's claim that truth is not what is real, but is whatever serves a particular purpose was one of the most subversive claims a philosopher ever made. James had set out as an apologist for Christianity, but by relativizing truth, he undermined it.

Linguistics produced similarly subversive developments—doubts about the reality of truth and whether language could express it. Ferdinand de Saussure, a teacher at the University of Geneva in Switzerland, is usually credited with decisive influence in this respect. But, like Einstein's, his influence was slow to affect the wider intellectual community. He began his lectures in 1907, but they were not published until after his death in 1913, in a form his pupils perfected or distorted. Mostly, they seemed revolutionary only to other students of language. But they contained a revolutionary idea: the distinction between social speech, the *parole* addressed to others, and subjective language, the *langue* known only to thought. As most students and readers interpreted it, Saussure seemed to say of language what Poincaré seemed to say of science—any language we use refers only to itself and cannot disclose remoter realities.

Mainstream philosophers were reluctant at first to pursue the implications of this idea. The dominant philosophy of the 1920s and 1930s, the years between the First and Second World Wars, was *positivism*, which asserted that what the human senses perceived was real and that reason could prove that what our senses perceive is true. But, as we have seen, developments in science and logic were making it impossible to feel such confidence. The most significant boost to the tradition Saussure inaugurated came in 1953 with the publication of *Philosophical Investigations*, by the English-trained Austrian philosopher, Ludwig Wittgenstein. The printed pages retained the flavor of lecture notes, full of anticipated questions from the audience. Wittgenstein's argument was that we understand language not because it corresponds to reality but because it obeys rules of usage. Therefore, we do not necessarily know what language refers to, except its own terms. Wittgenstein imagined a student asking, "So you are saying that human agreement decides what is true and what is false?" And again, "Aren't you at bottom really saying that everything except human behavior is a fiction?" Wittgenstein tried to distance himself from such devastating skepticism. The impact of a writer's work, however, often exceeds his intentions.

Equally disturbing, because of what it implied about human nature, was the work a linguist at the Massachusetts Institute of Technology, Noam Chomsky, published in 1957. Chomsky was impressed at how quickly and easily children learn speech. They can, in particular, combine words in ways they have never actually heard. He also found it remarkable that the differences between languages appear superficial compared with the "deep structures"—the parts of speech, the relationships between terms that we call *grammar* and *syntax*—that are common to all of them. Chomsky suggested a link between the structures of language and the brain. We learn languages fast because their structure is already part of the way we think. This was a revolutionary suggestion. Experience and heredity, nurture and nature, it implied, do not make us the whole of what we are. Part of our nature is hardwired and unchangeable. As Chomsky saw it, at least at first, this "language instinct" or "language faculty" was untouchable—and therefore perhaps not produced—by evolution. Chomsky's views remained theoretical and were, perhaps, beyond proof. But they resonated in minds worried about the problems of using language and science to access reality. He rapidly became the most-quoted figure in academic literature.

FINAL PASSAGE FROM *ULYSSES* (1922) BY JAMES JOYCE, perhaps the most famous stream of consciousness novel in the twentieth century.

James Joyce, Ulysses

. . . serene with his lamp and O that awful deepdown torrent O and the sea the sea crimson sometimes like fire and the glorious sunsets and the figtrees in the Alameda gardens yes and all the queer little streets and pink and blue and yellow houses and the rosegardens and the jessamine and geraniums and cactuses and Gibraltar as a girl where I was a Flower of the mountain yes when I put the rose in my hair like the Andalusian girls used or shall I wear a red yes and how he kissed me under the Moorish wall and I thought well as well him as another and then I asked him with my eyes to ask again yes and then he asked me would I yes to say yes my mountain flower and first I put my arms around him yes and drew him down to me so he could feel my breasts all perfume yes and his heart was going like mad and yes I said yes I will Yes.

Even more fundamentally, Chomsky argued that our language prowess, on which we tend to congratulate ourselves as a species—and which some people even claim is a uniquely human achievement—is like the special skills of other species: that of cheetahs in speed, for instance, or cows in ruminating. "It is the richness and specificity of instinct of animals," Chomsky said in a work of the mid-1980s, "that accounts for their remarkable achievements in some domains and lack of ability in others, so the argument runs, whereas humans, lacking such . . . instinctual structure, are free to think, speak and discover. . . . Both the logic of the problem and what we are now coming to understand suggest that this is not the correct way to identify the position of humans in the world." This chimed in with the disarming discoveries of primatology and paleoanthropology.[2]

By the time Chomsky entered the academic arena, unease and pessimism were rampant, especially in Europe and parts of Asia, where the material destruction and moral horror of the Second World War had been most keenly felt. The most widely accepted response to the war had emerged from a group of philosophers in Germany known as the Frankfurt School. Their great project was to find alternatives to Marxism and capitalism. They defined what they called alienation as the central problem of modern society. Economic rivalries and short-sighted materialism divided individuals and wrecked common pursuits. People felt dissatisfied and rootless. Martin Heidegger proposed a strategy to cope with this. We should accept our existence between conception and death as the only unchangeable thing about us and tackle life as a project of self-realization, of "becoming"—who we are changes as the project unfolds. This **existentialism** represented the retreat of intellectuals into the security of self-contemplation, in revulsion from an ugly world.

Existentialists. Jean-Paul Sartre (1905–1980) and Simone de Beauvoir (1908–1986), became icons of radicalism—she for her feminist classic, *The Second Sex*, he for the influence of his philosophy on postwar Western youth. At home in Paris, however, they seem like a model middle-class couple, stiffly sharing a newspaper in their under-decorated apartment.

Heidegger was discredited because he collaborated with the Nazis, a vicious German regime that provoked world war and massacred millions of people. In France in 1945, however, Jean-Paul Sartre (1905–1980) relaunched existentialism as a new creed for the post-war era. "Man," he said, "is . . . nothing else but what he makes of himself." For Sartre, self-modeling was more than an individual responsibility. Every individual action is an exemplary act, a statement about humankind, about the sort of species you want to belong to. Yet there is no objective way to put meaning into such a statement. God does not exist. Everything is permissible, and "as a result man is forlorn, without anything to cling to." "There is," he wrote, "no explaining things away by reference to a fixed . . . human nature. In other words, there is no determinism, man is free, man is freedom."

Sartre's version of existentialism fed the common assumptions about life of educated young Westerners in the 1950s and 1960s. Critics who denounced it as a philosophy of decadence were not far wrong in practice because it was used to justify every form of self-indulgence. Sexual promiscuity, revolutionary violence, indifference to manners, defiance of the law, drug abuse could all be part of becoming oneself. The social changes of the 1960s, to which we shall return in Chapter 29, would have been unthinkable without existentialism: beat culture and permissiveness—ways of life millions adopted or imitated—as well, perhaps, as the late twentieth-century's libertarian reaction against social planning. Existentialism was, briefly, the philosophical consensus of the West. But it never caught on in the rest of the world; and even in the West, people who saw more urgent problems than shaping one's personal future detested it. By the 1970s, a reaction was in the making: conservative in politics, mistrustful of materialism, inclined to religion, anxious to recover tradition and rebuild social solidarity—especially through the family. This was a global reaction. It was particularly strong in the Americas, while in Asia and Africa revulsion from Western-dominated thinking strengthened the trend.

The Diffusion and Transformation of Western Science

1842–1910	William James, American philosopher, developed the doctrine of pragmatism
1856–1939	Sigmund Freud, developer of psychoanalysis
1860s	China's "self-strengthening" program begins
1875–1965	Albert Schweizer, medical missionary to Africa
1879–1955	Albert Einstein, developer of the theory of relativity
1881–1938	Kemal Ataturk, founder of modern Turkey and proponent of secularism and Western science
1883	Western-style curriculum at Beijing School of Medicine
1885–1962	Niels Bohr, won Nobel Prize in 1922 for work on the structure of the atom
1891–1962	Ismail Mazhir, translator of Charles Darwin's work into Arabic
1897	Jagadis Chandra Bose awarded scientific research grant by the British viceroy
1901–1976	Werner Heisenberg, developed uncertainty principle
1902	Henry Poincaré questions the link between hypothesis and evidence
1903	Powered flight
1905–1980	Jean-Paul Sartre, French philosopher associated with existentialism
1907	Plastic invented
1912	Overthrow of the Qing dynasty increases pace of Westernization in China
1913	Indian *Journal of Medical Research* launched
1914	Science Society of China founded by Chinese students at Cornell University
1920	Royal Institute for Higher Technical Education founded in Indonesia
1928	Margaret Mead's *Coming of Age in Samoa* published
1931	Penicillin discovered
1944	Erwin Schrödinger predicts structure of the gene
1953	Ludwig Wittgenstein's *Philosophical Investigations* and Simone de Beauvoir's *The Second Sex* published

THE MIRROR OF SCIENCE: ART

The twentieth century was a graveyard and a cradle: a graveyard of certainties, the cradle of a civilization of crumbling confidence, in which it would be hard to be sure of anything. We can see the effect of this unsettling period—literally, see it—in the work of painters. Never more than in the twentieth century, painters tended to paint not the world as they saw it directly, but as science and philosophy displayed it for their inspection. The revolutions of twentieth-century art, the chronologies of artists' changing perceptions, exactly match the jolts and shocks science and philosophy administered.

In 1909, the Italian Emilio Filippo Marinetti (1876–1944) published a manifesto for fellow artists, proclaiming what he called **futurism**. At the time, most artists professed modernism: the doctrine that the new was superior to the old. Marinetti wanted to go further. He believed that what was traditional had not only to be surpassed but repudiated and wrecked. He rejected coherence, harmony, freedom, conventional morals, and conventional language—even conventional grammar—because they were familiar. Comfort was artistically sterile. Instead, futurism glorified war, power, chaos, and destruction, which

MAKING CONNECTIONS

TRANSFORMATIONS OF WESTERN SCIENCE AND THOUGHT

DISCIPLINE →	NEW THEORIES →	EFFECTS ON SOCIETY
Physics/Mathematics	Henry Poincaré: notes the elastic connection between hypothesis and evidence and how multiple hypotheses can fit results of experiments Albert Einstein: proposes and proves speed of light is a constant and time and space change with motion (theory of relativity) Earnest Rutherford: establishes basis of subatomic world Niels Bohr: light described as both waves and particles; links to Heisenberg's indeterminacy principle (uncertainty principle)	By mid–twentieth century, physics helped unleash the power of charged subatomic particles in practical technology including weapons (atomic bombs), communications (transistors, microprocessors, integrated circuits) The "new physics" also revolutionizes astronomy, chemistry, other physical sciences
Astronomy	Edwin Hubble: with large-scale telescopes, discovers that universe is expanding Development of radio telescopes, infrared and other means of examining distant stars	Combined with the "new physics" and jet propulsion, astronomical findings set the stage for exploration of solar system; they also challenge or confirm religious beliefs depending on religious standpoint; also raise new possibilities of extraterrestrial life
Biology	T. H. Morgan: demonstrates that genetic transmission influences physical characteristics Neuroscience demonstrates how mental functions operate within the brain	Advances in human biology lead to medical developments: controlling infections through use of antibiotics; controlling diabetes and developing large-scale preventive medical programs (inoculations, health education)

would shove humankind into novelty. Marinetti, with the followers he soon acquired, celebrated the beauty of machines, the morals of might, and the syntax of babble. Sensitivity, kindness, and fragility he dismissed as the mawkish values of old-fashioned art, created by the followers of the styles called romantic and aesthetic. Futurists preferred ruthlessness, candor, strength.

Marinetti's machine-age imagery appealed to a wide public and found echoes in the work of many artists, not all of whom accepted his brutal, radical program. Painters inspired by Marinetti's lectures painted "lines of force"—symbols of coercion. The excitement of speed—attained by the new-fangled internal combustion engine—represented for Marinetti the spirit of the age, speeding away from the past. The movement he founded united adherents of the most radical politics of the twentieth century: fascists, for whom the state should serve the strong, and communists, who hoped to incinerate tradition in revolution. The fascists and communists hated each other and relished the battles they fought with each other, first in the streets and later, when they took over states, in wars bigger and more terrible than any the world had ever seen. But they agreed that the function of progress was to destroy the past.

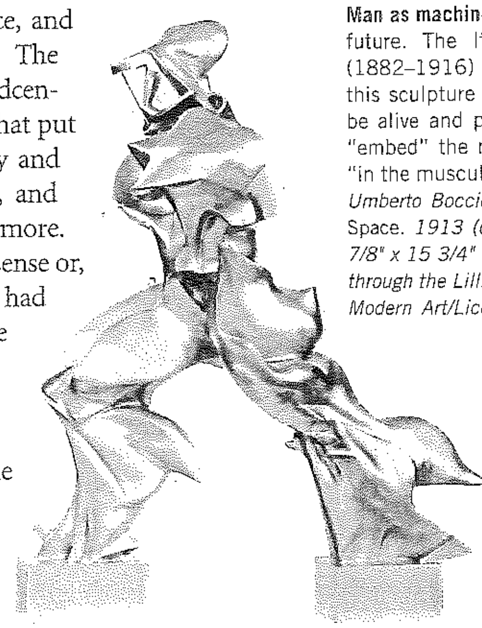
Emilio Filippo Marinetti, *"Futuristic Manifesto"*

In retrospect, Marinetti seems uncannily prophetic. The deepening destructiveness of wars and the quickening speed and power of machines did indeed dominate the future. The speeding machines turned the world into a global village where every place

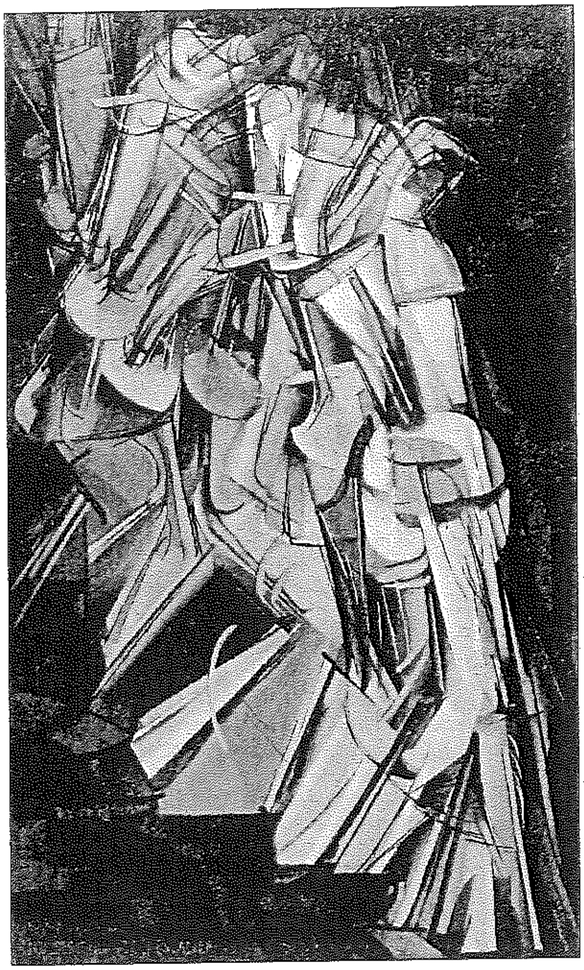
DISCIPLINE →	NEW THEORIES →	EFFECTS ON SOCIETY
Genetics	Search for genetic codes begins in 1944, to establish basic building blocks of life—by 1950s, DNA is discovered and belief that genetic codes could help solve medical problems	Fifty years of study leads to ability to manipulate genes of plants and animals to produce more beneficial results; more controversial is the focus on cloning and genetic engineering to develop most desirable humans
Primatology and paleoanthropology	Primatology: discovery that animals also have shared culture, language, toolmaking skills Paleoanthropology: discovery of features originally thought uniquely human (rituals, morality) among nonhuman ancestors	Widened research efforts in both disciplines; reinforced connection between all humans and led to deeper understanding of ecology, the study of interconnectedness of all life
Anthropology	Franz Boas: comparative study of societies shows that no race is superior to any other in brainpower, development of thought Margaret Meade: so-called primitive cultures free of neuroses and anxieties that plague Western society	New doctrine of cultural relativism focuses on studying communities in context of their traditions; widened appreciation for non-Western, native cultures (Native American, Samoan, etc.)
Psychology	Sigmund Freud: uncovered role of human subconscious in motivating actions; developed psychoanalysis to expose subconscious feelings, thoughts Development of new theories on child raising and education by Sigmund Freud and Ellen Key emphasizing childhood as a separate phase of life	Transformation of school curricula, child raising to conform with ideas of stages of child development; belief in subconscious strata of human mind leads to widespread interest in popular psychology including psychoanalysis and dream analysis
Philosophy and Linguistics	Henri Bergson and others reconceptualize time and causation as part of human-determined memory and experience F. de Saussure and others deconstruct language as human-constructed medium that cannot convey objective reality	New understandings of deep structures of language furthered by experiments of Noam Chomsky showing that language, speech, grammar, and syntax are linked to the brain, and are hardwired

was within, at most, a few hours' travel of every other place, and where information was accessible everywhere, instantly. The machines also achieved dazzling power to destroy. Toward midcentury, people devised massive gas chambers and incinerators that put millions to death and disposed of their bodies economically and efficiently. Bombs obliterated tens of thousands at a time, and spread deadly, corrosive radiation capable of killing millions more. Marinetti claimed, "The future has begun." It sounds like nonsense or, if not nonsense, a platitude, but, in a way, he was right. He had devised a telling metaphor for the pace of the changes that he and his contemporaries experienced. It was an exhilarating time, but it was also full of terror and foreboding.

Ultimately, Marinetti's future also failed, because tradition could never quite be outstripped. It always clung to the coattails of the speeding world. But the world had to pass through the flames of war and the furnace of tyranny before settling for mere instability and insecurity. By the end of the century, power seemed to have passed outside the realm of conventional politics. The programs of scien-



Man as machine, speeding and striding into the future. The Italian artist Umberto Boccioni (1882–1916) captured the spirit of futurism in this sculpture of 1913. "Our straight line will be alive and palpitating", he wrote, aiming to "embed" the math and geometry of machines "in the muscular lines of a body".
Umberto Boccioni, Unique Form of Continuity in Space. *1913 (cast 1931). Bronze, 43 7/8" x 34 7/8" x 15 3/4" (111.4 x 88.6 x 40 cm). Acquired through the Lillie P. Bliss Bequest. The Museum of Modern Art/Licensed by Scala-Art Resource, NY.*



Marcel Duchamp's painting, *Nude Descending a Staircase* (1912) was shockingly avant garde when first exhibited, but in retrospect, it seems representative of the most prominent trends in its day: dehumanizing, mechanistic, informed by science and technology, and subversive of tradition.

tists and technologists mattered more than those of politicians. Over people's lives, big business wielded more influence than voters exercised. Institutions of security, defense, and justice tended to slip not just out of democratic control, but even out of the control of governments. The power Marinetti praised—the power of science, the power of states—could not bring the world to order or order to the world.

Other artists, meanwhile, turned in disgust from the ideal of a machine-like universe and an engineered society, preferring a vision that atomic theory suggested—of an elusive, ill-ordered, uncontrollable world. In 1907, an artistic style called **cubism** began to hold up to the world images of itself reflected as if in a distorting mirror, shivered into fragments. Pablo Picasso and Georges Braque (1882–1963), the originators of the movement, denied they had ever heard of Einstein. But scientific vulgarizations, especially, of course, of the work of Poincaré, reached them through the press. As painters of an elusive reality from many different perspectives, they were reflecting the science and philosophy of their decade. Even Piet Mondrian (1872–1944)—the Dutch artist whose work so perfectly captured the sharp angles of modern taste that he represented the rhythms of boogie-woogie music as a rectilinear grid and Broadway in Manhattan as a straight line—had a shivered-mirror phase in the early years of the second decade of the century. Formerly, he loved to paint the trees along the river Geyn in his native Holland with romantic fidelity. Now he splayed and atomized them.

The French artist Marcel Duchamp (1887–1968) denounced his own expertise in science as mere smattering. But he, too, tried to represent Einstein's world. He called his painting, *Nude Descending a Staircase* of 1912, an expression of "time and space through the abstract presentation of motion." His notes on his baffling masterpiece of sculpture, *Large Glass*, revealed how closely he had studied relativity. Meanwhile, in 1911, the Russian artist Vasily Kandinsky had read Rutherford's description of the atom. "The discovery hit me with frightful force, as if the end of the world had come. All things become transparent, without strength or certainty." After that, he painted the world as he now saw it, suppressing every reminder of real objects. The tradition he launched, of entirely "abstract" art, which depicted objects unrecognizably or not at all, became dominant for the rest of the century. The new rhythmic beat of jazz and the noises of atonal music—developed in Vienna by Arnold Schoenberg from 1908 onward—subverted the harmonies of the past as surely as quantum mechanics began to challenge its ideas of order.

In art, the effects of the new anthropology were even clearer than those of the new physics. Picasso, Braque, and members of Kandinsky's circle (known as the Blue Rider School) copied "primitive" sculptures from museums of natural history, with the indigenous arts of the Pacific and Africa dominant at first. The range of influences broadened, as Western artists in the Americas and Australia rediscovered the art of native peoples. As in science and philosophy, Asian traditions made a big impact in the West in the last four decades of the century, especially in music, architecture, and stage design. The vogue for primitivism ensured that craftsmen outside Europe had a market for their traditional arts. Yet whenever innovations occurred in art, as in science, Western initiatives predominated globally throughout the century.

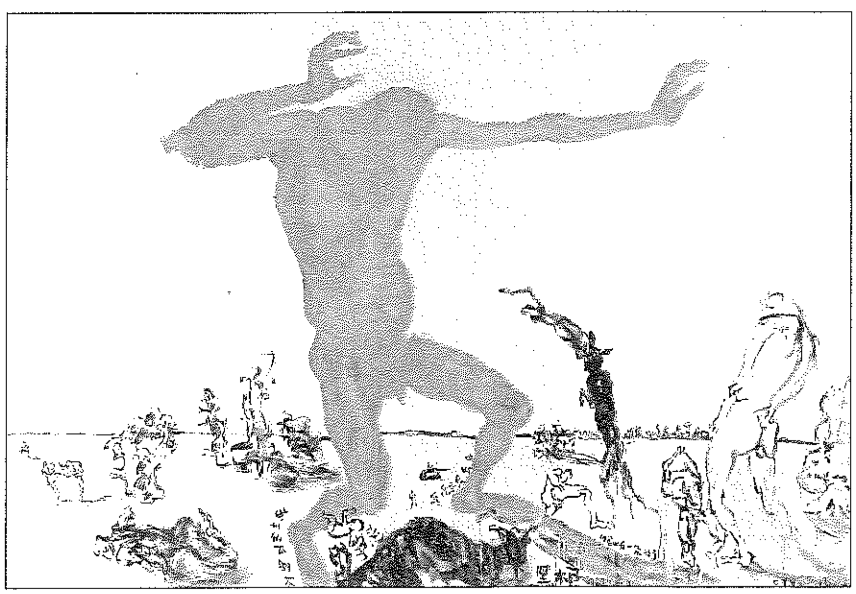
As in so many areas of modernization, Japanese artists led the way in assimilating Western influences. Outstanding painters, such as Kuroda Seiki and Wada Eisaku, were already studying in Europe in the 1890s and the early 1900s. In China, influence radiated chiefly from Russia, especially from the late 1940s, as Russian-inspired

Communists became first prominent, then all-powerful. Their characteristic subjects were stocky, heroic peasants and workers in poster-art style. This still dominated the art of Wang Guangyi (wahng gwang-yee) in the last years of the twentieth century. Meanwhile, however, China had opened up to every kind of Western influence. The outstanding young artist of the 1990s, Zhou Chunya (joe chwun-yah), was reported as saying, "Even though Western art dominates my painting style, I would say I am a Chinese painter ... because I maintain a Chinese lifestyle within myself." For painters working in the shadow of Western influence, his was a typical sentiment.

Among artists who resisted or selectively filtered Western influences, those from India were most conspicuous. To a great extent, this was thanks to Abindranath Tagore, who, at the end of the nineteenth century, rejected his Western-style training as a painter to find inspiration in Mughal art (Chapter 19). His followers and successors—notably Nandalal Bose (1882–1966)—made anticolonialism part of the message of their work. At the end of the century, many artists around the world turned to folk art to supply new styles. But, even painters who were most vocal in their rejection of the West were unable to escape altogether the magnetism of Western techniques, materials, and models.

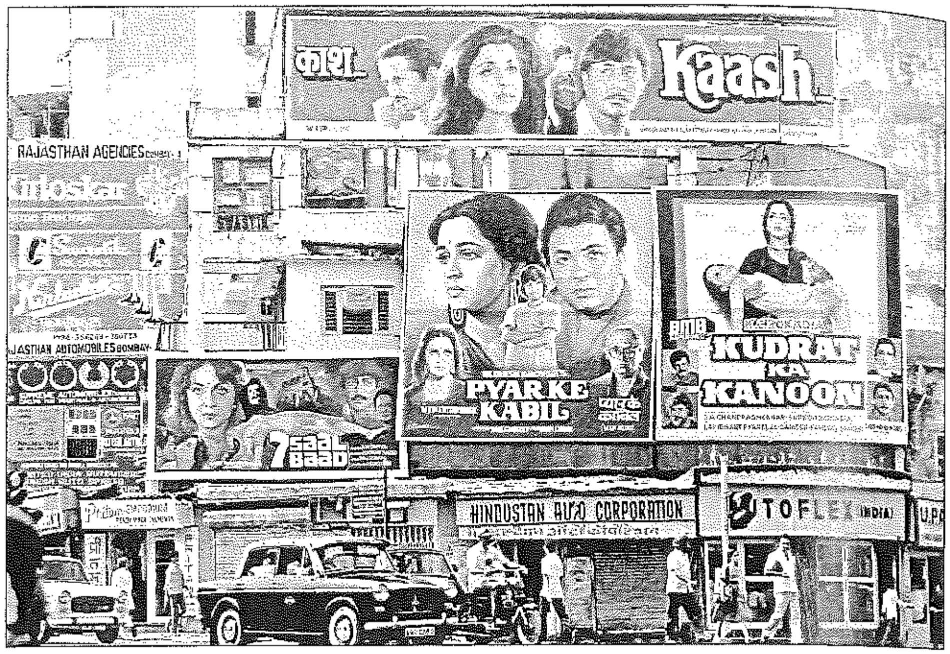
The novel, modeled on the Western tradition rather than the independently developed Japanese form, became a universal genre. Cinema, a new medium of Western origin, rapidly became the most popular art form in the world, and, although different cultures evolved their own schools of cinema, the American style, known as "Hollywood" from the Los Angeles suburb where most of the film studios had their headquarters, dominated the global market. New initiatives in sculpture and architecture, and some interesting new genres, such as video art and computer-generated art, depended on technologies that the West invented.

Paradoxically, it was in the West that the influence of Western art declined as the century wore on, but it took a long time for this to become apparent. Though governments patronized conventional artists, the characteristic art of the First World War and its aftermath was **dada**—externalized disillusionment, deliberately brutal, ugly, and meaningless. The "Dada Manifesto" of 1918 celebrated World War I, as the "great work of destruction." In Germany, Kurt Schwitters (1887–1948) scraped collages together from bits of smashed machines and ruined buildings. Max Ernst (1891–1976) exposed post-war nightmares, often using hostile materials—barbed wire, rough planks of wood. The artists who called themselves surrealists continued this trend in the 1920s and 1930s, reflecting psychology by creating paintings and films in which they aimed to externalize subconscious neuroses and desires. To some extent, their project overlapped with a school that established a more enduring tradition: expressionists, most of whom were more concerned with color and sometimes texture than with form, reached inside themselves and their subjects to represent emotion and mood.



Chinese and Western traditions. Born in 1955, Zhou Chunya has been able to marry Western and Chinese traditions in his art, thanks in part to his having studied in Germany. In many ways, his art recalls traditional Chinese painting, but the figures in his *Red Man* (2001) show the influence of classical Western sculpture, and its theme—humanity's apelike nature—is indebted to Western science and figures prominently in Western art.

After that, art seemed to lose some of its power to make people see the world afresh. **Surrealism** and expressionism were the last great global movements to start in the art world and overspill into ordinary people's perceptions. Plenty of great artists, challenged onlookers'



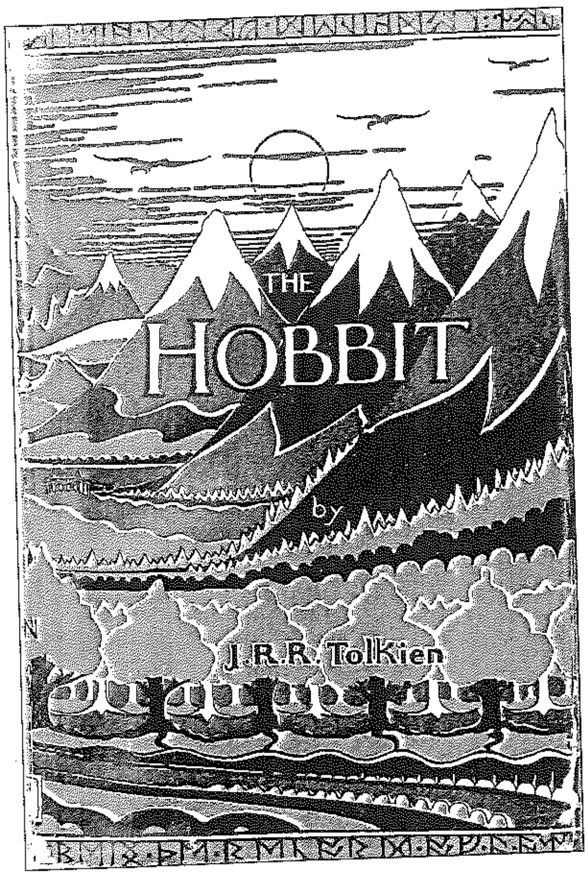
Bollywood. Few aspects of Indian life demonstrate the appropriation of Western culture so deeply as the Bombay (Mumbai) film industry, which has created its own imagery and values from a distant Hollywood model.

world picture, but none succeeded in changing it. Why was this? In part, it was because propaganda seduced art, especially the most powerful new art of the twentieth century, cinema. Most of the great movie directors and music composers of the 1930s and 1940s in Europe, America, and Russia got caught up in the ideological conflicts of the time. The Russian dictator, Joseph Stalin (1879–1953), wrote music criticism anonymously, dictated style for the Soviet Union, and insisted on "socialist realism" in all the arts as the only school worthy of state patronage and the only style in which it was safe for artists to paint, compose, or write. The German dictator Adolf Hitler (1889–1945) fancied himself a painter and architect and banned artists, writers, and composers whom he regarded as Jewish or "decadent." Even after the Second World War, and into the 1950s, American movie makers had to answer questions from Congress about how much "anticommunist" cinema they produced, and actors, directors, and screenwriters were banned if they were seen as being or even having once been procommunist.

More treacherously, art, like so much else in the twentieth-century West, became fodder for consumerism, commercialism, celebrity, and fashion. Artists escaped from political control by appealing to the mass market and to rich collectors. Salvador Dalí (1904–1989) was probably the most accomplished painter of the age in a technical sense. No one excelled him in mastery of his materials. His paintings, film–set designs, and the marketing of his images in poster form communicated the spirit of surrealism to a worldwide public. But many of his fellow artists hated him for his dedication to self-promotion and vulgar exhibitionism to boost the prices of his works. The great theorist of surrealism, André Breton (1896–1966), expelled Dalí from the movement and coined an anagram of his name: Avida Dollars. Picasso, the most prolific artist of the century, also became the richest by exhibiting uncanny business sense, and by becoming a celebrity, famous for being famous almost as much as for his art.

Art lost influence, too, because taste splintered. The pace of change quickened in art as in everything else. From the 1930s onward, the market lurched rapidly among fashions. Every school of artists had to repudiate every other school to attract buyers. Technology multiplied media exponentially from the 1960s onward, and the market responded by huddling in niches. Fans of one kind of music might know nothing of any other kind. Theatergoers might avoid films and film buffs never go to plays. The two groups might never communicate with each other, despite the obvious opportunities for cross-fertilization between their arts. To a large extent, intellectual and economic differences determined the niches of taste, as some artists, seduced by theory or lured into a price-range accessible only to the super rich, lost interest in communicating with people of modest means or ordinary education. This became especially the case from the 1960s, when artists influenced by the new theories in philosophy and linguistics lost belief in the power of symbols generally. Images, some of them came to feel, like words, have no direct relationship to reality.

Painting and sculpture yielded popularity to film and to mass entertainment industries. Arts suited to the new media—cinema, radio, photography, and the gramophone at first, television in the second half of the twentieth century, computers and video toward the century's end—spread secondhand experiences, received wisdom, and hand-me-down values. The artists who really touched people were cartoonists. Walt Disney (1901–1966)—a film studio chief who specialized in anthropomorphic characters and adaptations of famous fairy tales for the screen—became, perhaps, the world's most influential artist ever because his cartoon movies depicted the most commonplace emotions, morals, and character types in ways that people of all ages in all cultures could immediately grasp. Musical theater, sacrificing sophistication for memorable melody, displaced opera. Pop music was to art what factory products were to crafts: cheap to make and capable of generating huge profits. In the second half of the century, when—for reasons we shall discuss in the next chapter—vast masses of young people in the West acquired unprecedented spending power, the record industry became the home of the most socially revolutionary and subversive arts, a role writers had once filled. Now it was rock bands who issued messages of political protest and sexual liberation to the masses. These messages proved less saleable, in the long run, than escapism.



The Hobbit. The stories of the British writer J.R.R. Tolkien (1892-1973) launched a new type of literature: the fantasy novel, in which authors combined myths from different cultures to create imaginary worlds—located sometimes in the past, sometimes in space, sometimes in a "parallel universe"—where events could unfold without the limitations imposed by reason or reality. Science could not displace magic from people's minds and tastes. In some cases, the fantasy novel even became the basis of new kinds of religion.

By the end of the twentieth century, the most commercially successful genre was fantasy—the depiction of worlds that magic regulated or transformed, which suited computer-generated imagery. It seemed an ironic end to a century dominated by science, but it was symptomatic of the impatience with or revulsion from science that came to characterize popular responses. Meanwhile, the art form that attracted the most investment, and therefore attained the highest technical standards, was television advertising. Advertising jingles and images became the common artistic culture of the time—the only things you could rely on just about everyone to recognize. Sport, especially soccer, was the only rival—largely because it was telegenic and broadcast brilliantly all over the world.

Architecture ought to be the most popular art of all because people who never enter an art gallery live in some form of architecture and see buildings on their way to work. Indeed, after the Second World War, architecture replaced painting and rivaled cinema as the most socially powerful of the arts. The world had to be rebuilt, after the destruction of the war and the neglect of colonialism. However, doctrines that proved hostile to most people: functionalism and rationalism, which favored machinelike buildings, fashioned by necessity, stripped to their most elementary forms, angular in appearance, and unrelated to human scale, dominated the architecture of the period. So much had to be built so quickly that officialdom decided what and how to build, without giving much time or thought to the needs and feelings of the people who had to live in the huge apartment blocks, work in the offices, factories, and schools of the era, and recover or die in the hospitals. Only in the 1970s did architects and urban planners begin to turn back to popular demands, tear down some of the worst excesses of functionalism, and start again on a smaller scale and along more traditional lines.

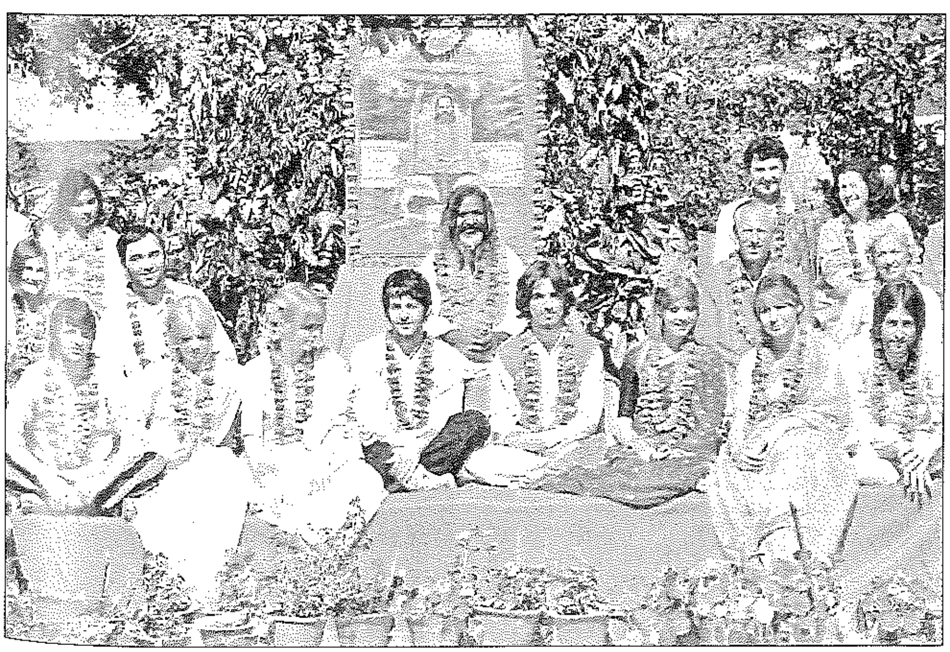
THE TURN OF THE WORLD

In the second half of the twentieth century, a reaction set in. The West rediscovered "Eastern wisdom," alternative medicine, and the traditional science of non-Western peoples. Other cultures renewed their confidence in their own traditions. One of the first signs was Niels Bohr's decision in 1947 to adopt a Daoist symbol on his coat of arms when the Danish government ennobled him. He saw the wavelike double curve, interpenetrated by dots, as a description of the universe that prefigured that of the quantum physics of which he was the leading practitioner. "Opposites," according to the motto on his coat of arms, "are complementary." In the same period, J. Robert Oppenheimer, the American physicist who led the research team that developed the A-bomb, was one of many Western scientists who turned to the ancient Indian texts, the Upanishads (oo-PAH-nee-shahdz), for consolation and insights, in a West disillusioned by the horrors of war (see Chapter 28).

Then in 1956, Joseph Needham, who had served as director of scientific cooperation between the British and their Chinese allies during the Second World War, began to publish, in the first of many volumes, one of the momentous books of the twentieth century, *Science and Civilisation in China*, in which he showed that, despite the poor reputation of Chinese science in modern times, China had a scientific tradition of its own, from which the West had learned the basis of most of its progress in technology until the seventeenth century. Indian scientists, meanwhile, had made similar claims for the antiquity—if not the global influence—of scientific thinking in their own country. In the 1960s, India became a favored destination for young Western tourists and pilgrims in search of values

"Modern" Art

1866–1944	Vasily Kandinsky, Russian artist, launched tradition of entirely abstract art
1872–1944	Piet Mondrian, Dutch abstract artist
1876–1944	Emilio Filippo Marinetti, proponent of futurism
1881–1973	Pablo Picasso, cofounder of cubism
1882–1966	Nandalal Bose, Indian artist, incorporated anticolonialism in his work
1887–1968	Marcel Duchamp, French artist influenced by Einstein's theory of relativity
Early twentieth century	Karoda Seiki and Wada Eisaku, Japanese painters, create works that assimilated Western influences
1918	Proclamation of the "Dada Manifesto"
1920s and 1930s	Emergence of surrealist and expressionist movements



The Beatles in India. Maharishi Mahesi Yogi, who claimed to be able to levitate and to procure world peace through meditation, was the most commercially successful of the Indian gurus who became fashionable in the West in the 1960s. Here members of the star rock band, the Beatles, sit at his feet. They incorporated some Indian influences into their music, and George Harrison (center, right) remained a devotee of the Maharishi's techniques.

different from those of their own cultures (Chapter 29). By the 1980s, some Western scientists, dissatisfied with the terms at their disposal for describing the complexities of the cosmos that their work revealed, turned to Asian philosophies. Zen Buddhism (Chapter 14) and Daoist descriptions of nature provided some Westerners with models to interpret the universe that seemed to match scientific discoveries.

Even in medicine, the showpiece science of Western supremacy in the early twentieth century, non-Western traditions gained ground. Westerners with experience of the world often came to respect and learn from the healers they met far afield. Edward Hume himself commented favorably on the work of traditional Chinese herbalists, from whom he had learned much during his years at the Yale Clinic in Changsha. But it took a long time for such respect to become general in the West. In the 1980s, the World Health Organization began to realize the value of traditional healers in delivering health care to disadvantaged people in Africa. In 1985, for instance, Nigeria introduced alternative medicine to hospitals and health-care centers. South Africa and other African countries set up similar programs.

Meanwhile, in the West, traditional healing arts of non-Western peoples attracted big followings. Ethnobotany became fashionable, as medical practitioners discovered the healing plants of Amazonian forest dwellers, Chinese peasants, and Himalayan shamans. Scientists—led by anthropologists impressed by the knowledge of medicinal plants that the peoples they encountered in their work had—began to appreciate that so-called primitive peoples had a cornucopia of useful drugs unknown to Western medicine. Traditional medicine had never died out in India and China. In a remarkable reversal of the direction of influence in the late twentieth century, Western patients seeking alternative medicines turned to Indian herbalism and Chinese acupuncture, along with other forms of traditional medicine in both countries. Westerners began to travel to China and India to study herbal treatments, just as at the beginning of the century, Asian students had headed to the West for the medical learning fashionable in their day. Western demand for alternative medicine became an economic opportunity for Chinese and Indian physicians in the West. The world had come full circle since Edward Hume's day.

African healing cult. In Cape Town, South Africa, a ritual of initiation into Ngoma—a shamanistic cult widespread in Africa. Practitioners use music and dance to attain a trance-like state in which they communicate with spirits, usually to access powers of healing.

In the first half of the twentieth century, the intellectual hegemony of science was linked, unchallengeably, with the global dominance of the West. All the major new scientific initiatives came from Europe and America. The rest of the world could only endure this supremacy or attempt to imitate it. In the 1960s, however, the pattern began to shift significantly. Western scientists began to turn to non-Western, and especially to Asian, traditions of thought to help interpret some of the conflicting data their observations accumulated. These contradictions seemed, especially to nonscientists, to expose the imperfections of science as a system of knowledge that could explain the universe. Non-Western countries, especially in east and south Asia, imitated Western technologies so well that they began to build up enough wealth to invest in their own scientific institutions.

Meanwhile, revulsion from science increased prestige for what came to be known as alternative methods. Some people, especially professional scientists, remained convinced of the all-sufficiency of science and scorned these trends. Their critics called them scientistic. Toward the end of the century, divisions—sometimes called culture wars—opened between apologists of science and advocates of alternatives.

The search for the underlying or overarching order of the cosmos seemed only to lead to chaos. "Life is scientific," says Piggy, the doomed hero of William Golding's novel of 1959, *Lord of the Flies*. The rest of the characters prove him wrong by killing him and reverting to instinct and savagery. Golding died in 1993, hailed as one of the great storytellers of the century, largely because of the impact of this one novel, which seemed to be an allegory of its times. Science—in most people's judgment—soared and failed. It sought to penetrate the heavens and ended by contaminating the Earth. Among its most influential inventions, the effects of which are among the subjects of our remaining chapters, were bombs and pollutants. The expansion of knowledge added nothing to wisdom. Science did not make people better. Rather it increased their ability to behave worse than ever before. Instead of a universal benefit to humanity, science was a symptom or cause of disproportionate Western power. Under the influence of these feelings, and in response to the undermining of science by skepticism, an antiscientific reaction set in the late twentieth century. It generated conflict between those who stuck to Piggy's opinion and the vast global majority who—as we shall see in Chapter 29—turned back to religion or even magic to help them cope with the bewildering world of rapid change and elusive understanding.

William Golding's *Lord of the Flies* in the movie version directed by Peter Brook (1963). The story of the British choirboy-castaways who turn to tyranny and savagery when cut off from the disciplines of adult control is not just an antidote to the idealization of childhood but also a reminder of the fragility of civilization. In this scene the gang turns on their companion, Piggy, who maintains a touching faith that "Life is scientific."

The revival of unscientific ways to picture reality surprised most observers. But by making the cosmos rationally unintelligible to most people, science actually stimulated religious revival. Quantum science encouraged a revival of mysticism—a "reenchantment" of science, according to a phrase the British theologian David Griffin coined. Quantum experiments accustomed people to reliable observations that no one has been able to check objectively and to valid experiments that no one can repeat. Motions we cannot measure, events we cannot track, causes we cannot trace, and effects we cannot predict all became familiar and seemed to license metaphysical and even supernatural explanations. Modern Japan is a land of high-tech Shinto, where spirits infest computers and where an office tower of steel and plate glass can be topped off with a shrine to Inari, the fox-god. Some medical practitioners collaborate with faith healers. Even religious fundamentalism—one of the most powerful movements in the late twentieth-century world—owed something to science.

The last wave of revulsion from science—or, at least, from scientism—in the twentieth century was a form of humanism: a reaction in favor of humane values. Science seemed to blur the boundaries between humans and other animals, or even between humans and machines. It seemed to take the soul out of people and substitute genes for it. It seemed to make freedom impossible and reduce moral choices to evolutionary accidents or genetically determined options. It turned human beings into subjects of experimentation. Ruthless regimes abused biology to justify racism and psychiatry to imprison dissidents. Extreme scientism denied all nonscientific values and became, in its own way, as dogmatic as any religion. The "new humanism" was much more, however, than an antiscientistic reaction. It tended to blame religion—or, at least, religious conflicts—as much as science for the failures of history, and its thinkers and practitioners sought a morality based on universal or potentially universal values. More than either science or religion, the barbarities of the violent, conflictive political history of the twentieth century stimulated the new humanism.

For the story of politics in the twentieth century matched that of science. In politics, too, the new century opened with new departures. The world's first full democracies—full in the sense that women had equal political rights with men—took shape in Norway and New Zealand. In 1904–1905, Japanese victories in a war with Russia foreshadowed the end of white supremacy. Encouraged by Japan's example, independence movements sprang into action in Europe's overseas empires. In 1911, the first great "rebellions of the masses" began. Contrary to the expectations of Karl Marx, these were not launched by urban workers, but by peasant revolutionaries in Mexico and a combination of underemployed intellectuals and disaffected soldiers in China. In Mexico, the effect was to end the power of the two elements of society that had been dominant since colonial times: the church and the big landowners. In China, the Qing dynasty, which had reigned since 1644, was overthrown, the mandate of heaven abolished, and a republic proclaimed. This was an extraordinary reversal for a system that had survived so many convulsions for more than 2,200 years, and a sign that no form of political stability, however longstanding, could now be taken for granted. Both revolutions soured, turning into civil wars, breeding dictators. This too was an omen of the future. Most of the many violent regime changes of the twentieth century had similar consequences.

CHRONOLOGY

1856–1939	Sigmund Freud, developer of psychoanalysis
1858–1942	Franz Boas, anthropologist, proved that races are of equal intelligence
1860s	China's "self-strengthening" program begins
1866–1944	Vasily Kandinsky, Russian artist, launched tradition of entirely abstract art
1883	Western-style curriculum at Beijing School of Medicine
1871–1937	Ernest Rutherford, postulated concept of the atomic nucleus
1875–1965	Albert Schweizer, medical missionary to Africa
1876–1944	Emilio Filippo Marinetti, proponent of futurism
1879–1955	Albert Einstein, developer of the theory of relativity
1881–1938	Kemal Ataturk, founder of modern Turkey and proponent of secularism and Western science
1881–1973	Pablo Picasso, cofounder of cubism
1882–1966	Nandalal Bose, Indian artist, incorporated anticolonialism in his work
1885–1962	Niels Bohr, won Nobel Prize in 1922 for work on the structure of the atom
1891–1962	Ismail Mazhir, translator of Charles Darwin's work into Arabic
1897	Jagadis Chandra Bose awarded scientific research grant by the British viceroy
1901–1976	Werner Heisenberg, developed uncertainty principle
1902	Henry Poincaré questions the link between hypothesis and evidence
1903	Powered flight
1905–1980	Jean-Paul Sartre, French philosopher associated with existentialism
1906	15,000 Chinese study science abroad
1907	Plastic invented
1913	Indian *Journal of Medical Research* launched
1914	Science Society of China founded by Chinese students at Cornell University
1920s and 1930s	Emergence of surrealist and expressionist movements
1920	Royal Institute for Higher Technical Education founded in Indonesia
1925	Scopes "Monkey" Trial
1928	Margaret Mead's *Coming of Age in Samoa* published
1931	Penicillin discovered
1944	Erwin Schödinger predicts structure of the gene
1953	Ludwig Wittgenstein's *Philosophical Investigations* published
1956	Publication of Joseph Needham's *Science and Civilisation in China*